

Collector's Edition: 20th Anniversary of Apollo 11

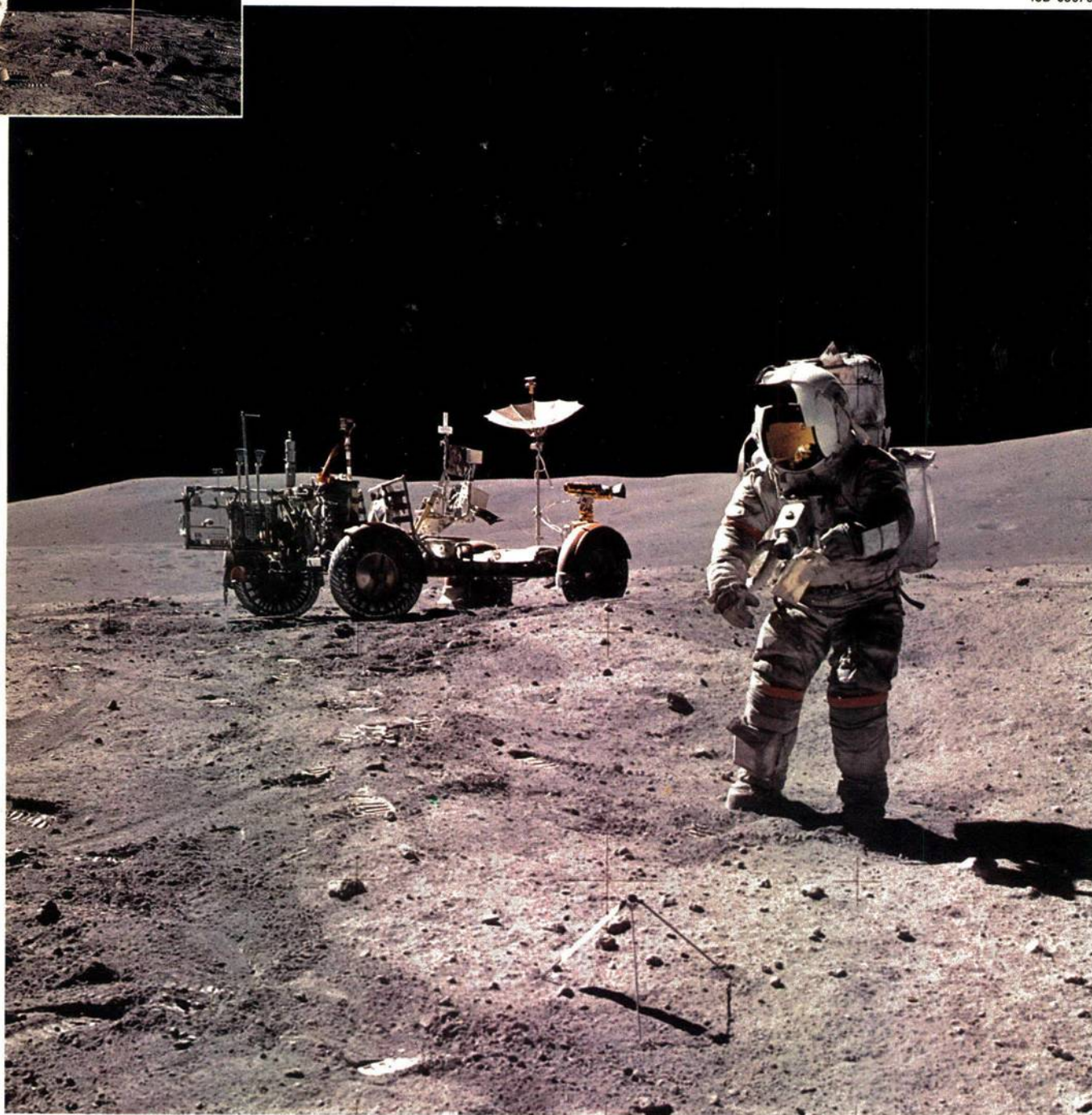
ASTRONOMY



"One Small Step"
The Epic Journey Remembered
Apollo Gave Us a New Moon

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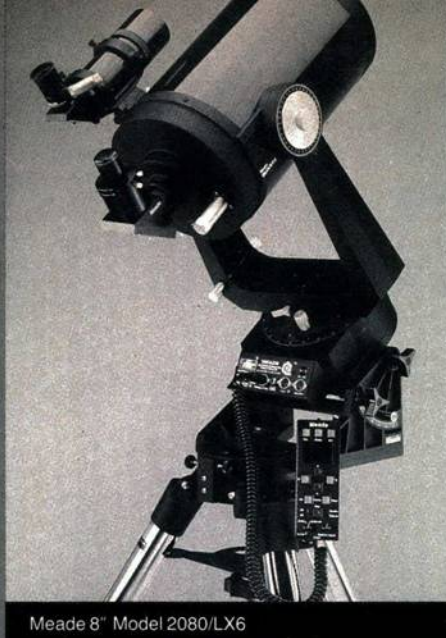
Revisit the Lunar Landing Sites



Meade® Wide-Field f/6.3 SCT's:



"Recently at a club star party we had the opportunity to test the Meade 10" Model 2120/LX6 telescope. The first object observed was Jupiter, at 182X with the Meade Ultra Wide Angle 8.8mm eyepiece. Six cloud belts, as well as the Great Red Spot, were visible in great detail. I also observed a large festoon on the North Temperate Zone. Sharpness and contrast were equal to, if not better than, conventional f/10 optics. After simple polar alignment, the LX6 quartz drive tracked perfectly at high power. The view of the Orion Nebula (M42) was spectacular! The trapezium stars were sharp, bright pinpoints and the nebulosity overflowed the field of view in my Super Wide Angle 40mm eyepiece. The full extent of the Rosette Nebula (NGC 2237) was easily visible, and the Christmas Tree Nebula (NGC 2024) was an easy target for the f/6.3 optics. Even the Horsehead Nebula (IC 434) was seen visually with a nebular filter—the first time we had ever seen the Horsehead through a 10" telescope. Other club members were equally impressed. Everyone commented on the ease of use and features of the LX6 handheld Electronic Command Center. Enclosed are two photos taken with the LX6 and the Meade Off-Axis Guider. The M42 photo is a 5 minute exposure, the Horsehead a 7-



Meade 8" Model 2080/LX6

"On the night of January 29, 1989, under the clear, dark skies at Star Hill Inn, three members of the Lehigh Valley Astronomical Society from Pennsylvania, who were guests at Star Hill, and I were observing with a Meade 8" LX6 and one of your 32mm Super Wide Angle eyepieces. To our amazement, we were able to detect, without a nebular filter, the Horsehead Nebula visually... quite a feat for an 8" telescope! In addition we observed that M33 exhibited notable spiral structure. Again, very commendable for an 8" telescope. That night, we all agreed that we had seen objects and detail in the 8" LX6 that are normally reserved for 10" and larger apertures. Among our rental equipment at Star Hill Inn is a Meade 10" LX6 and we have been equally pleased with its performance. To sum it up, I think the Meade 8" and 10" LX6 models are outstanding instruments. Congratulations!" —**Phil Mahon**, Sapello, NM, Owner, Star Hill Inn astronomical retreat.

"I purchased one of your 10" Model 2120/LX6 telescopes late in 1988. Having access to a range of telescopes of various apertures, I am astonished that my 2120/LX6 can outperform instruments with significantly larger diameter. The common thread of

User Reports on the LX6 Revolution

minute exposure. I am thrilled with the results and look forward to taking more astrophotographs with the Meade 2120/LX6." —**Douglas Finch**, Birmingham, AL, Amateur Astronomer/Retail Telescope Store Manager.

"I took a Meade 10" LX6 to the annual Southern Cross Winter Star Party in the Florida Keys in February. Since the instrument was new, I figured I would use the time as a good "shakedown." Starting out, I was impressed that, using the Meade 40mm Super Wide Angle eyepiece, the contrast was excellent—in fact, good enough to allow viewing of the fringe nebulosity portion of M42, areas which I have previously only known through photographs. Equally impressive was the Meade CAT Computer Aided Telescope system. While some amateurs around me were wondering whether NGC 3372 was sufficiently above the horizon to be seen, all I had to do was punch in its CNGC number on the CAT console and was guided precisely to the object. Although low on the horizon, the "keyhole" of NGC 3372 was easily seen. The CAT told me exactly where to look and I suspect I was the first one to see it. Of all the telescopes which I have used over the years, I am most impressed with the Meade 2120/LX6 with CAT computer system." —**Jim Brown**, Atlanta, GA, Amateur Astronomer/Past President of the Astronomical League.

"I was frankly skeptical that your new 10" f/6.3 optics could be as good as you claim, but several weeks of testing the 2120/LX6 side by side with other f/10 SCT's (including several competitive models) have fully validated everything you say. Using my Meade Ultra Wide Angle 8.8mm eyepiece at 182X, I obtained an image of Mars I thought possible only with long focal length refractors. And, as you state in your catalog, using wide angle eyepieces with the LX6 on star fields and nebulae permits a visual experience impossible to achieve with f/10 Schmidt-Cassegrains. I never thought I would see the day when a 10" SCT yields an actual, fully corrected field 1.7" in diameter! As a serious observer of more than 20 years standing, I could not be more pleased with the instrument." —**Paul Hobbs**, Monrovia, CA, Amateur Astronomer.

"After my first few times using an 8" LX6, I think it is a VERY impressive telescope. When a friend and I

took one out several weeks ago for the first time and pointed it at Jupiter, after allowing the instrument to reach ambient temperature, the LX6, notwithstanding its much wider field of view, compared very favorably with f/10 SCT's with respect to contrast and image quality. In addition, my friend took his first deep-sky shot on that night and in about a minute using Kodak 3200 film got one heck of a shot of M42." —**Mark Saperstein**, Boston, MA, Amateur Astronomer/Advertising Manager for optical specialty store.

"I previously have written to you about the excellent optics of your Series 4000 eyepieces and, after testing your new 10" Model 2120/LX6, I am compelled to write again. In one sentence: the 2120/LX6 is the most impressive commercial instrument I have yet seen. Under critical examinations, stellar diffraction patterns are superb both inside and outside of focus. The telescope's optical quality compares very favorably with large professional instruments, including a 12" Zeiss refractor and the 24" Clark refractor at Lowell Observatory, that I have used in over 35 years of professional work as a staff astronomer. Focal images are sharp and crisp; in applications where high contrast characteristics are important (such as in observing the "eyes" of the Owl Nebula, M97, or structural variations in the main spiral arm of the Whirlpool Galaxy, M51), the 2120/LX6 performs impressively. The image of Saturn is beautifully defined, showing subtle belt detail and the crepe ring with surprising boldness for a 10" telescope. The LX drive and control system is everything claimed. During an M51 exposure, it was possible for me to leave my observatory, pour myself a cup of coffee and return several minutes later to find the guide star still positioned on the crosshairs of my guiding eyepiece. The telescope's fast f/6.3 optics, combined with the LX6 electronic control system, add a professional dimension to the skilled observer's investigations. I would strongly recommend the Meade 2120/LX6 to anyone." —**Paul Roques**, Williams, AZ, Professional Astronomer.

my observations with the LX6 has been the ability to see diffuse nebulosity and filamentary detail that I've never before witnessed, except in photographs or through telescopes with over twice the aperture. Being able to discriminate such fine detail in faint objects could only be attributable to the superb contrast of the LX6 optical system. It is obvious the system is baffled for optimum contrast. As to some specific objects observed:

The Pleiades—Using the Super Wide Angle 40mm eyepiece with averted vision, I could see the curved filamentary structure around the main stars—something I've only seen in pictures before—plus vivid blueness in the four main stars.

Crab Nebula—With the Meade Ultra Wide Angle 14mm eyepiece, a very easy ability to observe the filamentary structure—my first time seeing this detail other than through a 24" instrument.

Veil Nebula—Extremely easy to observe—the best I've ever seen it. Lucid wide bright area narrowing down to smaller nebulosity.

Galaxy M82—I have never seen the filamentary dust lanes as well in a 10"-aperture telescope.

Christmas Tree Nebula—was an easy subject, as was the *Rosette Nebula*." —**Brad Brotherton**, Milwaukie, OR, Amateur Astronomer.

Price Increase!

Prices on all Meade 8" and 10" LX5 and LX6 Schmidt-Cassegrains will be increased 5% to 10% on July 15, 1989. See your Meade dealer now for current lower pricing.

Complete Catalog Package #89C—\$3.00—Includes catalogs and bulletins on the entire range of Meade astronomical telescopes, Series 4000 eyepieces, and accessories.

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ON THE COVER:

Astronaut John Young was photographed near the lunar rover as he prepared to take a sample during the *Apollo 16* mission to the Moon's southern highlands. Inset: Buzz Aldrin and the flag at Tranquility Base.



MAN ON THE MOON

Buzz Aldrin posed for his *Apollo 11* crewmate Neil Armstrong, who is reflected in the helmet visor along with lunar lander *Eagle*.

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July 1989

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REMEMBER THE MOON

July 20, 1969. How old were you twenty years ago? Where were you? What were you doing? How did you feel about the Moon landing? Were you even aware of it?

Do you remember watching the ghostly figures of Neil Armstrong and Buzz Aldrin bouncing across the television screen in the low lunar gravity? Were you elated? bored? entranced? cynical? Or did all those feelings mix inside you, as they did for me, until you weren't sure how you felt.

Twenty years later the Moon landing shines in my mind as the premier event of that year and the cap of a tumultuous decade. Nineteen-sixty-nine was both a zenith and nadir in American life. Now freed from the political and cultural turmoil of the times, the achievements of the Apollo crews, engineers, and NASA management seem all the brighter. And after the loss of *Challenger*, the derring-do of the Moon crews seems all the more gutsy.

To celebrate this twentieth anniversary of the first human landing on another world, I asked senior editor Robert Burnham to prepare this special Apollo collector's edition of *ASTRONOMY*. In this issue you'll read about *Apollo 11*'s flight to the Moon, find out what we learned about the Moon from the Apollo missions, and look into the future another twenty years toward the next round of lunar landings. In addition, we show you exactly where on the Moon each Apollo mission landed, so you can pinpoint in your telescope where humans once walked among the craters.

To help you feel the thrill of the Apollo moonwalks as the astronauts experienced them, Robert spent a week at the Lunar and Planetary Science Institute in Houston, Texas, where he examined every photograph the astronauts took while on the lunar surface. It was a daunting task. "The photos were in great thick binders, each with hundreds of pictures in it, and there were 160 binders," Robert told us when he got back to the office. "As soon as I saw them, I realized it would take me days to go through them."

From Robert's search came the splendid portfolio of images in this issue of *ASTRONOMY*. I hope you'll sit down with this issue and slowly page through the images. Gaze at them for a long time. Let the reality of the moonwalks sink in: People from the planet Earth once walked on another world.

Sincerely,



Richard Berry
Editor-in-Chief

ASTRONOMY

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U.S. Newsstand Distribution
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Canadian Newsstand Distribution
 Telemedia Dist., Toronto, Ontario M4S 3B3

World Newsstand Distribution
 Boats International, Inc., New York, NY 10019

Moon Projection

I wanted to use my new Odyssey 8 telescope during a Full Moon recently and, considering my limited options, decided to do some lunar observing.

When I focused on the Moon, I found it was too bright to observe through the eyepiece directly. I grabbed a piece of paper and tried to project the image on to it. I focused the image while my cousin held the paper. The results were amazing.

We observed maria, large craters, and mountain ranges. We shared the view with our families and were able to point out features such as Tycho, Archimedes, and the Apennine Mountains.

I know about using this technique to project the Sun, but I have never heard of observing the Moon this way. This could be a very successful procedure for star parties and public observing nights.

—Mike Nollett, Valentine, Nebraska

Celestron Defends Ultima 8

We at Celestron wish to respond to some of the issues raised in your review of our Ultima 8 telescope ("ASTRONOMY Tests Celestron's Ultima 8," May 1989).

We believe that the Celestron-Byers drive is entirely adequate for long-exposure astrophotography. Every telescope has some residual driving errors that need to be corrected, and the user can correct this with the Ultima 8's built-in drive corrector. This gear system has been used to produce superb astrophotographs, including many published in *ASTRONOMY*.

Likewise, the tripod supplied with the Ultima 8 has been used extensively to help produce fine astrophotographs. As your reviewer noted, we recommend that high-quality astrophotography be done from a sitting position with the tripod as low as possible to the ground for maximum stability.

Our new foam-fitted case is the finest offered for this class of instrument. It is made of high-density polyethylene that feels flexible but is extremely tough for rugged handling. Before adopting the new case, we tested the handle and rivets and found they will securely hold a load of over five hundred pounds. The foam provides added protection against bumps and jars.

We'd also like to point out that the batteries used in the drive electronics are not ordinary rechargeable "D" cells, but rugged, sealed, heavy-duty, industrial-type, lead-acid batteries that hold their charge for many months.

We at Celestron try to be responsive to our customer's needs. When we designed

Several years ago, I purchased a 10" Schmidt-Cassegrain telescope. On this new instrument, I carefully compared the performance of the most respected brands of eyepieces before concluding that the **Tele Vue** Plössls were giving me the best views. Along with 4 of your Plössls (55, 26, 17 and 13mm) and your 2.5x Barlow, I bought a Giant Off-Axis Guider, which I frequently use as a telecompressor. Although I have always been pleased with your eyepieces, there are limits to just how much a long-focal-length telescope can be telecompressed! ■

For over three years, I have wanted a second instrument for rich-field observing and photographing. Although your **Renaissance** is most impressive, it just wasn't quite the instrument I wanted and the **Oracle** was a bit too small. Then came **Genesis**. Knowing what a stickler you are for details in both design and production, plus my total satisfaction with your eyepieces; sight unseen, I bought a **Genesis** based solely on those facts and your ads in the magazines. ■

I took delivery of my **Genesis** at the Texas Astronomical Society's meeting on 7/22/88. Even with all the light pollution in that North Dallas parking lot, my new **Tele Vue** 32mm Wide Field eyepiece, at less than 16x, clearly resolved Saturn's rings as separate from the disc. When a friend asked to try his 12 mm Nagler-II with his 3x Barlow, I knew I had bought a "winner." The Cassini Division was as sharply defined as I have ever seen it plus the surface and ring detail was second only to a view I once saw under a Texas Star Party's dark skies through a nearly \$20,000, 10.7" f/15 Maksutov! ■

The reason for this letter is simple. I have now had my first opportunity to take my new **Genesis** out to the T.A.S.'s dark-sky observing site (100 miles north of Dallas). In short order, the **Genesis** had attracted a group of experienced observers (most holding full Messier Certificates) away from their larger telescopes. Simply, **Genesis** stole the show! Except for an occasional comparison view, my 10" Schmidt-Cassegrain sat idle because I was seeing far greater clarity and detail with my new **Genesis**. Although I had with me a full set of filters (Deep Sky, U.H.C., O-III and H-β), none were ever used. ■

While I had anticipated a gorgeously resplendent Double Cluster, it was truly more dazzling than I expected. But, some real surprises lay ahead. Take M-33 in Triangulum: 4" just isn't enough aperture for such a diffuse spiral, right? WRONG! With the 32mm Wide Field, I was seeing tremendous detail in a galaxy over 1/3 the width of the field. I could write paragraphs describing a California Nebula covering half the field plus all the glorious sights through Sagittarius and Scorpius like the Lagoon, Trifid and M-21 all in the same field; or, four gleaming globulars, M-22 & 28 with NGC-6638 & 6642. ■

DEAR MR. NAGLER:

While the Great Andromeda Galaxy (M-31) spread across more than 2/3 of the field, we were all alternating time at the eyepiece, trying to see who could count the most dust lanes. It was more beautiful than even the photographs from the leading observatories. I have never seen M-110 appear as large relative to M-31. One observer even held his

hand in front of the eyepiece and suggested that we try observing a projected image! While that may have been beyond even **Genesis**' capability, it does prove we were looking at no dim M-31. There

was a debate over which eyepiece provided the better view: the 13mm Nagler's greater contrast and detail or the 32mm Wide Field's greater coverage. Each outperformed the other in its own way and both provided splendid views. ■

All night, comments from seasoned observers included a thesaurus-full of one word expletives of praise, wonder and astonishment. While glued to the eyepiece, other comments included: "...but this is ONLY a 4-inch" to "Boy! You sure made no mistake in buying this one" and "Oh, No!... How am I ever going to make my wife see the need?". One observer even yelled to a friend across the field, "Get over here if you want to see what Rich Field is SUPPOSED to look like." Personally, I can hardly wait to start taking astrophotos with it. ■

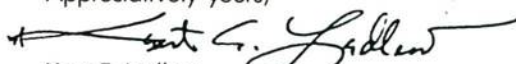
In case you could have possibly missed my point: I am totally enthralled with my new **Genesis**. Mr. Nagler, what you have created with your **Renaissance** and **Genesis** telescopes has filled a void, beyond binoculars and yet still permitting the beauty of deep sky objects to be viewed 'in context' without resorting to the usual solution of over-magnification that reveals detail at the expense of sacrificing perspective. ■

Because our dark sky observing location attracts late-night dewing and humidity, I appreciate your design consideration of including the fluorite element as a totally internal component, inaccessible to dew, condensation or scratches. ■



It would have been impolite of me not to write and tell you just how much of a Big Bang your **Genesis** telescope has already created in my deep sky observing. ■

Appreciatively yours,


Kent E. Ledlow

Tele Vue®

20 Dexter Plaza, Pearl River, NY 10965

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WHY ISN'T THERE A GOOD \$200 SCOPE?

by Alan Dyer

Program director at the Edmonton Space Sciences Centre, Edmonton, Alberta

The world needs a good, low-cost telescope. As someone who has been presenting astronomy to the public for several years, I find the lack of a quality telescope in the under-\$300 range an embarrassment. When I worked in a telescope store, I regularly had to face discouraged customers who couldn't shell out the \$500 to \$1,000 that has long been the cost of the proverbial "decent" telescope. All I could do was turn them away or sell them an inferior product and hope they would survive the disappoint-

The lack of a quality, low-cost telescope for the beginning observer is an embarrassment.

ment and stay in the hobby.

Despite the crying need in the marketplace for a quality starter scope, the major telescope manufacturers continue to concentrate on expensive high-tech telescopes. Yes, there are people who want these top-of-the-line scopes, but for every one of them who walks into a telescope store, there are a hundred or more who simply want a good, low-cost, no-frills scope for themselves or their children.

To meet this demand, import companies have long flooded the market with the ubiquitous Japanese-made 60mm refractors. These telescopes have different brand names, but they all seem to come from the same factory. Even with the rising cost of imported scopes, telescopes from the Orient still dominate the low-end market.

U.S. telescope manufacturers should take on this foreign competition and produce a well-designed beginner's telescope for the mass market. Even if the telescope has to be made off-shore to reduce labor costs, the design could be made to U.S. standards. This means materials that won't snap in two under the slightest stress, a simple but solid altazimuth mount with slow-motion controls, and — the most neglected feature — a finder scope that actually allows you to find things.

While there have been some attempts to produce this type of low-cost tele-

scope, most have fallen short of the mark. For example, at our planetarium store we recently purchased a batch of low-cost refractors from a major U.S. manufacturer. We knew full well that these would be Japanese units, but because they were advertised as being made to the specifications of an American company, we expected the quality to be a cut above the department store model. What we got was a shaky mount, no slow-motion controls, sub-sized eyepieces, and an inadequate finder scope. In other words, the same old junk.

An innovative telescope designer could choose several different approaches to building a beginner's scope. It could be a small refractor. There's certainly nothing wrong with an 80mm or even a 60mm refractor as a starter scope. Celestron's Firstscope 80 seems to fit this description, but at \$450 and up it is still beyond the budget of most beginners.

As an alternative to the small refractor, why not produce a low-cost Dobsonian reflector? If something as complex as a computer-controlled Schmidt-Cassegrain can be mass-manufactured, then surely a telescope as simple as a Dobsonian could be stamped out with assembly line techniques and still have quality optics and a good profit margin for everyone involved.

One possible drawback to a reflector design is the simple fact that to many people reflectors don't look like a telescope. Beginners prefer refractors because they understand them. Even two hundred years after its invention, the basic Newtonian reflector is still a mystery to most people. In particular, beginners have difficulty aiming a reflector.

No matter what design is selected, a low-cost scope will need promotional support to succeed. Dealers should urge manufacturers to redirect their marketing resources to promote this telescope through the mass media as the superior alternative to the usual imported scope. The lower profit margins of a low-cost telescope would be offset by bringing more first-time buyers into the hobby who will eventually buy additional accessories and telescopes. And that's when the profits can be made.

Unlike most of the cheap beginner's telescopes on the market today, sold with a "take-the-money-and-run" mentality, this ideal starter scope would be one that dealers could sell with pride. It would be a telescope to spark a lifelong interest, not the cause of frustrating moments under the stars. □

the Ultima 8, we increased the size of the right ascension knob and lock by 50 percent for convenient one-hand operation, and we plan to replace the small set screw on the finder scope shortly with a knurled knob. This is typical of how our products are improved over the years.

Celestron proudly stands behind its claim that the Ultima 8 is the finest 8-inch Schmidt-Cassegrain in the world. — Alan R. Hale, President, Celestron International

Raving about Reviews

Much to my delight, I noticed on the cover of the May 1989 ASTRONOMY that you had an article on the new Celestron Ultima 8 telescope. I immediately turned to the article and began to read. Eureka! It was a genuine review. This is the kind of information I had hoped for years to find in astronomy publications.

Your article pointed out areas that the manufacturer can improve and the prospective buyer can check. I hope equipment tests and reviews will become a regular feature. New and experienced amateurs alike benefit from an unbiased look at equipment that they might be considering for purchase. — Tom Bar-kume, Woodinville, Washington

"Color" Correction

I was very impressed with the clarity and conciseness of Christopher Sneden's "Reading the Colors of the Stars" (April 1989). However, the third paragraph on page 38 contains an erroneous statement about the nature of light: "The energy carried by a photon is directly proportional to the wavelength." The statement should read: "The energy carried by a photon is *inversely* proportional to the wavelength," because a photon's energy increases as its wavelength decreases.

My thanks to Dr. Sneden for an otherwise highly informative description of starlight. — Al Berni, Seattle, Washington

An Astronomical Catastrophe

We know that stars explode. Galaxies collide. Planets are destroyed. Such drastic destinies are common in the universe. So it should be of little surprise that a human creation like the NRAO 300-foot radio dish collapsed and turned into rubble. — Bassel A. Reyahi, Tulkarm, Israel

ASTRONOMY welcomes comments, suggestions, corrections, and additional information on articles and astronomy. Send your letters to: ASTRONOMY Letters, 1027 North 7th Street, Milwaukee, WI 53233. Letters may be edited for length and clarity. □

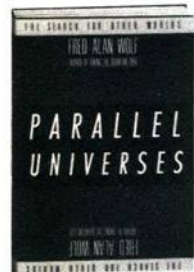
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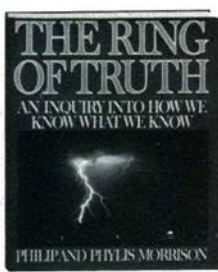
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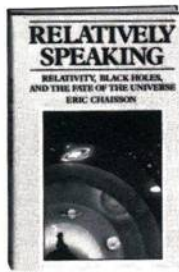
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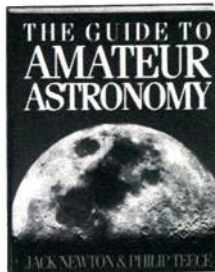
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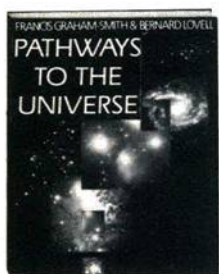
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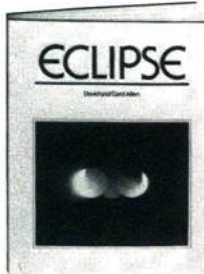
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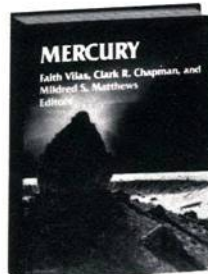
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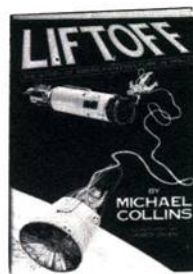
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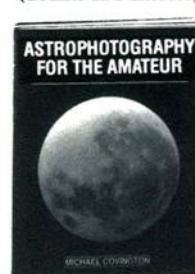
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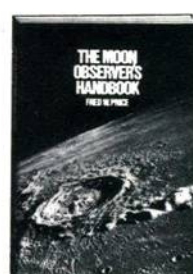
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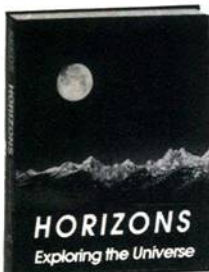
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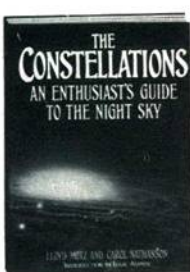
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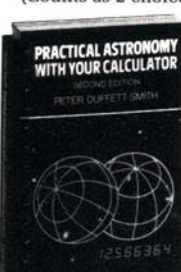
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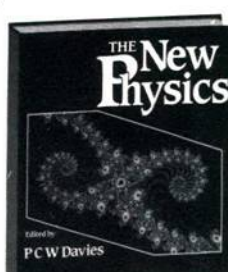
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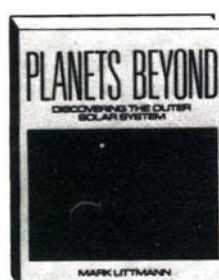
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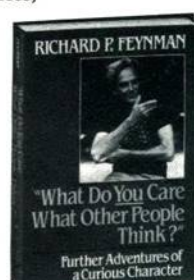
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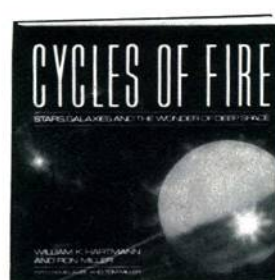
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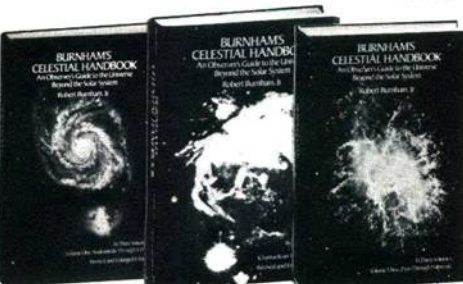
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GIANT SOLAR FLARE STUNS ASTRONOMERS

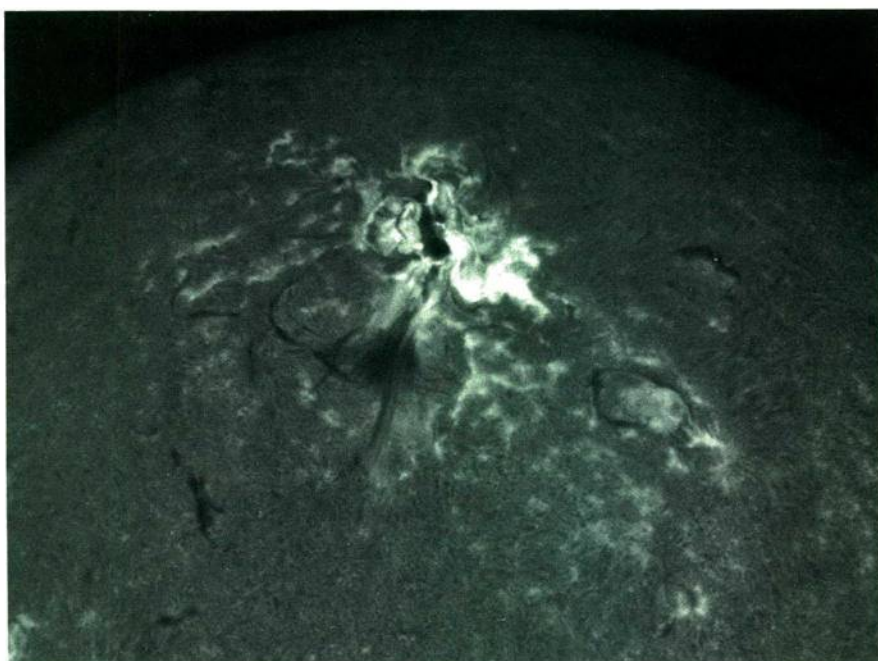
A little after 9 a.m. EST on March 6, 1989, the Sun produced one of the most energetic flares in over twenty years. The flare was observed by the *Solar Maximum Mission* satellite and the *Geostationary Operational Environmental Satellites*, in addition to numerous optical and radio telescopes on the ground. According to Patrick McIntosh of the National Oceanic and Atmospheric Administration's Space Environmental Laboratory in Boulder, Colorado, readings by sensitive detectors on the satellites at the high-energy end of the spectrum went off the top of the scale for 27 minutes.

The first indications that the Sun was on the verge of doing something dramatic came on March 4 at 11:20 a.m. when observers at the Ramey Solar Observatory, part of the Air Force's Solar Observing Optical Network at Holloman Air Force Base, New Mexico, reported "surge activity" on the eastern limb of the Sun. Surge activity is a term used to describe the energy emitted from a jet of solar material falling back into the chromosphere, the stratum of the Sun's atmosphere between the visible surface and the corona. The cause of the surge activity: a solar flare on the Sun's limb.

As it turned out, this observation was a prelude to two weeks of record-setting solar activity. An hour after the peak of the March 6 flare, the ultraviolet spectrometer and polarimeter aboard *Solar Max* recorded a bright ultraviolet loop extending over 40,000 miles from the Sun's limb. The curvature of this feature indicated that it was a large-scale magnetic loop, resulting from hot gas being issued from the flare and cooled by radiation.

The flare was one of the largest x-ray events ever recorded, according to Judy Nelson of ST Systems Corporation in Lanham, Maryland. Nelson, who forecasts solar conditions for scientists monitoring the *Solar Max* satellite at NASA's Goddard Space Flight Center in Maryland, said, "The flare was the largest observed by *Solar Max*." She also reported that the x-ray detectors on the *Geostationary Operational Environmental Satellites* "were saturated."

Flares were almost continuously observed by astronomers during the two weeks it took for the active region to make its way across the Sun's disk. Richard Schwartz of ST Systems reported that between March 6 and 19, high-energy x-ray bursts from flares were observed at a rate of about thirty-two per



LIKE A CRACK IN THE SUN, one of the brightest solar flares in twenty years erupted on the Sun's eastern limb in March. Temperatures within the flare were estimated to be about 10 million kelvins; the area immediately surrounding the flare is about 3 million kelvins.

day, which exceeds the previous peak by 50 percent. During one five-day stretch, Schwartz said, more than 250 flares were detected.

As the active region crossed the Sun's meridian, the emission from the series of flares began to have terrestrial effects. On March 13, a geomagnetic storm spawned by the flares overloaded Earth's magnetosphere, disrupting radio communications and triggering power surges that left 6 million people in Quebec without power for over ten hours. People living along more southerly latitudes in the Northern Hemisphere weren't complaining, however. Brilliant aurorae were reported as far south as the Bahamas.

Astronomers, of course, were ecstatic. The many observations at different wavelengths of the same active region of the Sun will enable them to compare notes and perhaps better understand flare phenomena. Moreover, said McIntosh, comparisons of the emission from these flares with emission from flares recorded during the previous solar cycle may reveal something about the internal processes controlling the energy of flares from cycle to cycle.

By mid-April, the Sun had quieted down, leaving solar observers in the

post-flare doldrums. "It's too quiet," Nelson remarked. "I think we'd all like something exciting to happen."

With the expected peak in solar activity roughly a year away, said McIntosh, that's a very real possibility. "We think from the cadence we've seen in other solar maxima that we will have a strong outburst in the next six months, though it might not be as intense as the March 6 outburst."

STRUGGLING TO UNDERSTAND THE SUPERNOVA 1987A PULSAR

Since January 1989, astronomers have been trying to understand the rapid pulsations emanating from the heart of supernova 1987A (*AstroNews*, May 1989). Although astronomers expected to find a pulsar (a rapidly rotating neutron star that emits narrow beams of energy) left by the supernova explosion, no one expected a pulsar like this. The object appears to spin nearly two thousand times a second, which is close to the velocity at which it would fly apart, and to have a magnetic field a thousand times weaker than that of other young pulsars.

In the past few months, there have

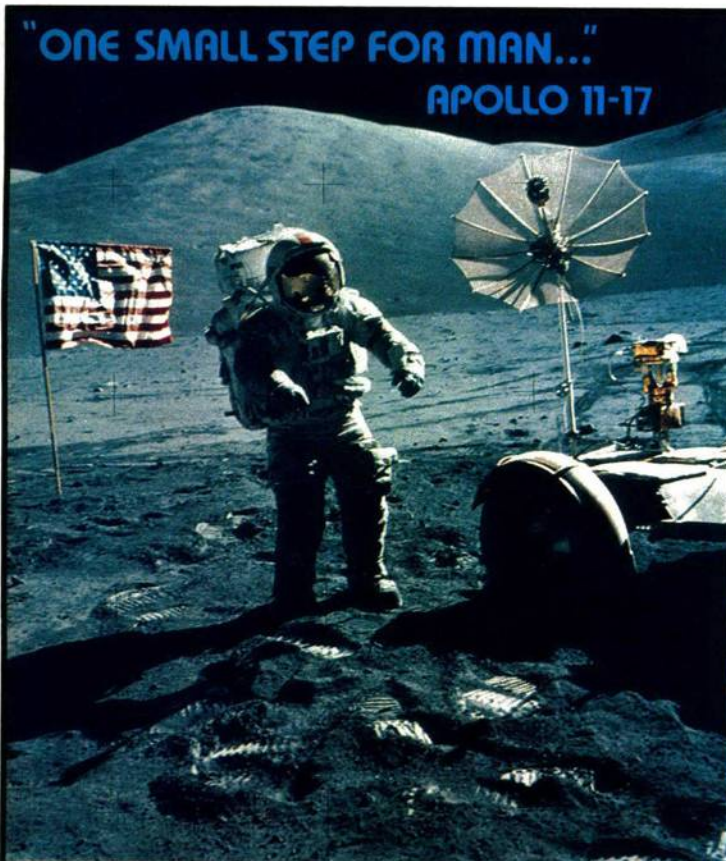
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been a number of attempts by theoreticians to explain the bizarre properties of this object. Although several plausible scenarios have emerged from these efforts, the exact nature of the object remains elusive.

One theoretical approach is to accept the observations at face value — the object is a pulsar that spins three times faster than any known pulsar and possesses a weak magnetic field — and explain how such an object might arise.

Lick Observatory astronomer Stan Woosley and Roger Chevalier of the University of Virginia believe the pulsar was "spun-up" shortly after the explosion. They speculate in *Nature* (March 23, 1989) that the newly formed pulsar spun at a typical rate of a few to a hundred times a second. However, within a day after the explosion roughly 0.1 solar mass of material fell back on to the pulsar. This caused the star to spin dramatically faster, in the same way an ice skater spins more rapidly by pulling in his or her arms.

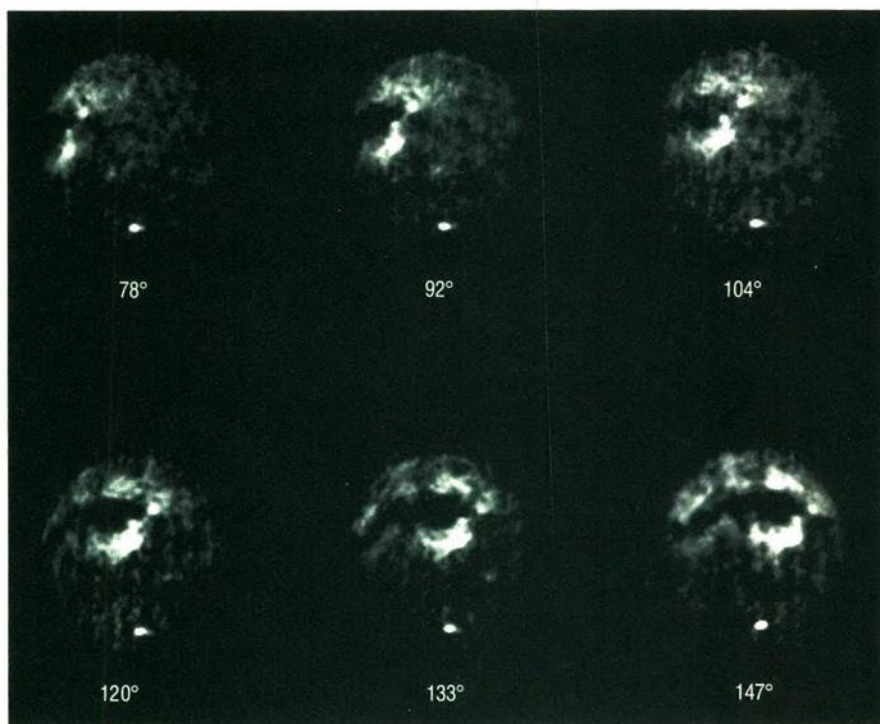
If these assumptions are true, the unusual characteristics of the 1987A pulsar could be a direct result of the progenitor star being a blue supergiant. Most supernovae in massive stars occur in the much less dense red supergiants, where only one-hundredth as much material would fall back on to the collapsed core.

A different interpretation of the observations comes from Columbia University astronomers Qingde Wang, Kaiyou Chen, Thomas Hamilton, Malvin Ruderman, and Jacob Shaham in the same issue of *Nature*. They believe the pulsating signal arises not from a rapidly spinning pulsar, but from a slowly spinning neutron star that is vibrating two thousand times a second.

Much like a bell reverberating after it is struck, the neutron star could be vibrating periodically in the aftermath of the supernova. The observed light pulses would arise when heavy ions are accelerated by shock waves created at the star's surface by the vibrations.

An attractive aspect of this scenario is that the observations are explained by a neutron star with a typical spin rate and magnetic field. If the Columbia researchers are correct, the vibrations will last for several years before dying out.

To get a better idea of what really lies at the heart of supernova 1987A, astronomers need more observations. Unfortunately, the pulsating signal has not been seen since its discovery. Most astronomers believe the object appeared through a thin spot in the expanding debris and will reappear as the surrounding nebula gradually thins. But until then, all the theories will remain untested.



RADAR IMAGES of the Red Planet reveal a Mars different from the visible planet.

MARS BY RADAR

The first synthetic aperture radar images of Mars, taken on October 22, 1988, show regions with strong (bright) and weak (dark) reflections at a wavelength of 3.5 centimeters. The scientists making the images were intrigued to note that except for a small bright spot located at the bottom center of the disk, the radar "topography" bears no close relation to the actual topography of the Red Planet. The findings will probably force geologists to revise their understanding of the Martian subsurface, but it is too early to say how.

A team of five planetary scientists from Caltech and the Jet Propulsion Laboratory, led by Duane O. Muhleman, used the Goldstone antenna of the Deep Space Network to send a 350-kilowatt radar signal to Mars. The returning signals, which reflected off the surface or penetrated at most only a few feet, were picked up by the Very Large Array radio telescope in New Mexico and were then computer-processed into images. (The number next to each radar picture is the longitude of the central meridian; the vertical stripes are imaging system artifacts.)

The bright point at the disk's bottom center marks the location of the permanent south polar cap, a deposit of carbon dioxide ("dry") ice, possibly with some water ice mixed in. "The bright region

crossing the meridian at 133° is a totally nondescript area south of the volcano Arsia Mons," said Muhleman. "Olympus Mons, another volcano, is rising in the northwest (upper left) at meridian 120°, but its echo is relatively weak and we get little or no return from the caldera at its summit, which ought to be more radar-bright than it appears."

Despite a resolution of about 70 kilometers at the center of the disk, the radar generally did not image the known topography of Mars. "We can't discern Valles Marineris," Muhleman remarked. "And neither Argyre nor Hellas [two large dune-filled impact basins] stand out."

The large dark region that is crossing the meridian at 133° proved enigmatic also, because it absorbed the radar signal entirely, returning no echo whatever. "We have no idea what kind of geology causes this," said Muhleman. "But we're calling it Stealth."

LIGHTS OUT IN FLAGSTAFF

Astronomers in Flagstaff, Arizona, are celebrating a major victory in their war against light pollution. Last March the Board of Supervisors of Coconino County, which includes Flagstaff, passed what astronomers consider the most rigorous anti-light-pollution ordinance ever enacted. The ordinance restricts certain

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types of lighting and regulates all outdoor lighting within the county. In the city that pioneered the first lighting ordinance in 1958, astronomers feel they have successfully protected the future of the skies over Lowell Observatory and the U.S. Naval Observatory, the city's two major astronomical institutions.

"The ordinance is the first in the country that restricts the amount of light that can be shed on each acre of land," said Christian B. Luginbuhl, an astronomer at the Naval Observatory and a principal author of the ordinance.

Before appearing at meetings of the county supervisors, Luginbuhl and Wes Lockwood, an astronomer at Lowell, prepared a detailed photometric study on the lighting practices of Flagstaff businesses. The report was instrumental in convincing the administrators to favor the astronomers' point of view.

"The report shows everything from gross underillumination to gross overillumination," said Lockwood. "Although the ordinance is now law, we'll still use these data to help businesses improve their lighting, save money, and improve the look of the city."

The Flagstaff law restricts the total output of light based on a system of zones lying at increasing distances from the observatory grounds. In Zone One, within 2.5 miles of the telescopes, the total outdoor light cannot exceed an average of 25,000 lumens per acre. Twice that amount of light is permitted in the zone 2.5 to 7 miles away from the observatories. Land in Zone Three, the areas between 7 and 35 miles from the observatories, can be illuminated with as many as 100,000 lumens per acre.

The ordinance also restricts the types of lighting that can be used in various zones. In addition to banning new mercury-vapor light, the ordinance requires that low-pressure sodium lights — the preferred choice because their light can be filtered out by astronomers — must be fully shielded and aimed so they illuminate only the property on which they rest. Four other types of lighting are permitted in certain areas, as long as they are properly aimed and shielded: 200 watt or less incandescent bulbs, 150 watt or less tungsten-halogen bulbs, 50 watt or less high-pressure sodium bulbs, and 40 watt or less fluorescent bulbs.

A grandfather clause protects lighting already in place, although now all lights must be properly aimed and shielded. Owners of properly shielded mercury vapor lights will be able to replace the bulbs until January 1, 2006, when the clause expires and all lighting must conform to the intent of the law.

Space News

A ROBOT-BUILT LUNAR OBSERVATORY

Is it possible that when we return to the Moon astronauts won't have to come along in order to build a large radio telescope on the surface? A research firm in Columbus, Ohio, is looking into that possibility for NASA. According to this scenario, sometime before 2010 astronomers may be receiving data from a lunar radio telescope built entirely by a robotic rover.

A conceptual design completed by Battelle Columbus Laboratories outlines ways in which such a vehicle could construct a radio telescope with minimal assistance from either Moon-based astronauts or Earth-based operators. NASA's Johnson Space Center requested the study as one possible strategy in the agency's mission to explore scientific uses of space.

The six-wheeled lunar construction vehicle, similar to the Apollo lunar rover, would operate autonomously and would deploy itself after landing. Two arms mounted near the front of the robot would be used to install the radio telescope, and a cartlike payload bay would carry the antennae and other necessary equipment.

The radio telescope, formally called the Very-Low Frequency Array, would not be the traditional dish-shaped structure but a series of several hundred independent antennae placed in a spiral pattern across the lunar surface. The array would be constructed on the floor of the Tsiolkovsky crater, a relatively smooth expanse about seventy miles wide on the lunar farside.

The robot would first map the construction site, scanning the area one section at a time as it rolls across the crater. Computer controls on board would memorize

previously encountered obstacles and map routes to facilitate return trips to maintain equipment or construct new antenna sites.

David Easter, principal project engineer, said controllers on Earth would communicate with the robot via a relay satellite positioned at the L2 Earth-Moon libration point. The satellite would transmit digital and video data to the vehicle and back to Earth. — *Bob D. Gibson*

WHERE WERE YOU ON JULY 20, 1969?

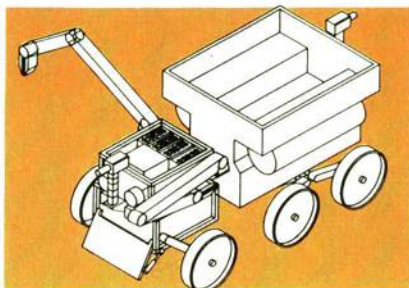
Buzz Aldrin and Neil Armstrong were walking on the Moon, fellow *Apollo 11* astronaut Michael Collins was orbiting overhead, and about 600 million people around the world were watching on television as mankind took its first steps onto another world.

Exactly twenty years later, the *Apollo 11* astronauts will be at the National Air and Space Museum in Washington, D.C., to commemorate the first moonwalk. A ceremony will be held outside the Museum at 11 a.m. on July 20, part of a day-long celebration that includes replaying television coverage of the event.

The Museum will be open until 1:30 a.m. so that the original television coverage can be shown on closed-circuit monitors at the time it took place two decades ago. At precisely 10:56 p.m., visitors will again see Neil Armstrong take his "small" step onto the lunar surface.

If you can't get to Washington for this event, you can watch the moonwalk again on television if your cable service carries the Arts & Entertainment channel. "Moonwalk: As It Happened 1969" is a three-part special that will be broadcast at the times the major *Apollo 11* events took place. "Liftoff" will be shown on July 16 at 9:20 a.m. EDT; "Moonwalk" on July 20 at 10:30 p.m.; and "Splashdown" on July 24 at 1:30 p.m. You can also watch the series as a three-hour special on July 23 at 3 p.m.

The *Apollo 11* astronauts will also be appearing on July 15 at the Space & Rocket Center in Huntsville, Alabama. Several other *Apollo* astronauts will be on hand during a week of special events in Huntsville, the home of NASA's Marshall Space Flight Center.



AN UNMANNED ROVER being studied by NASA could construct a radio telescope on the Moon without the aid of astronauts.

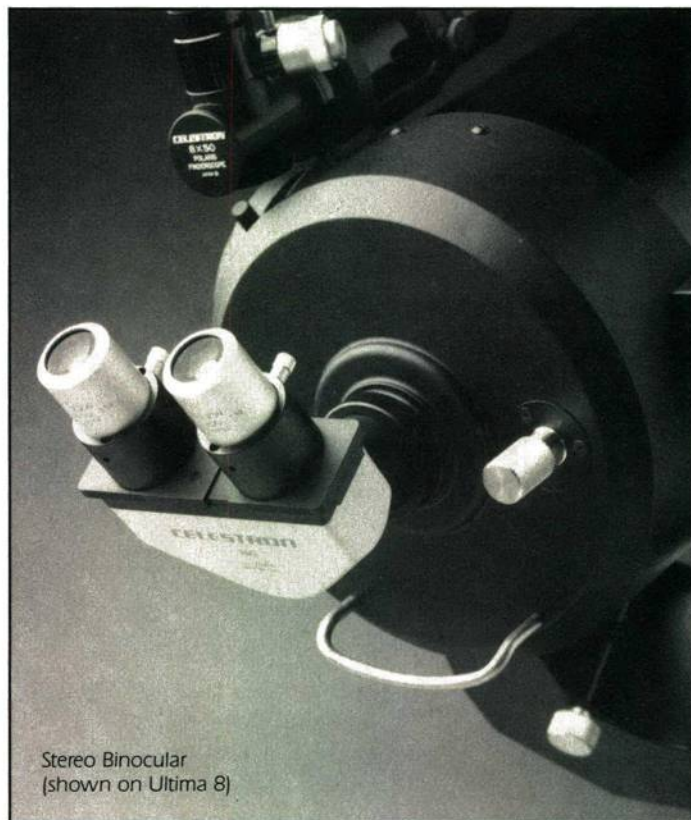
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MORE SPACE DEBRIS DATA NEEDED, REPORT STATES

It's now official: Space debris has been declared hazardous to the health of the U.S. space program. A top-level government study headed by NASA and the Department of Defense released a report in February that calls for a coordinated effort to curb the growth of high-velocity fragments of satellites and rockets in low-Earth orbit. The destructive force of this debris poses a real threat to spacecraft at this altitude.

The report recommends that all federal agencies involved with civil, military, and commercial launches design future launch vehicles, satellites, and space tests to minimize the amount of debris they produce. The report also recommends continued research into improving spacecraft shielding and the development of a long-term strategy to deal with the debris problem.

One of the report's major recommendations is to find out more about the amount of space debris now in orbit. Current radar tracking technology can only see objects larger than 4 inches in diameter, which is only 0.2 percent of the total number of debris particles in space. NASA is working on a new ground-based radar system that would be able to detect objects as small as half an inch in diameter. That system will be operational in 1992.

Data from the new radar system will be used to decide how much protective shielding Space Station *Freedom* will need to carry. Although only half an inch of shielding is currently planned for the station, up to an inch may be needed to adequately protect the spacecraft.

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Amateur News

COURT RULES AGAINST LIGHT POLLUTER

In a precedent-setting case in Warsaw, Indiana, Judge Douglas B. Morton of the Kosciusko County Circuit Court has ruled that two defendants whose yard light interferes with a neighbor's observatory must shut off the light at night. The case marks the first such ruling in the history of Indiana, and perhaps in the United States. The case demonstrates that amateur astronomers can claim light pollution as a "private nuisance" that interferes with the darkness of their sky.

In 1976 Alan Mitterling constructed an observatory south of Warsaw and later installed a 16-inch reflector for viewing planets and deep-sky objects. For nine years he enjoyed dark skies because of cooperative neighbors who shut off lights when Mitterling observed. In 1985, however, a couple moved next door to the observatory and would not acknowledge Mitterling's requests for minimal lighting.

Mitterling and his wife Nancy took the neighbors to court. After showing Judge Morton photographs of the light pollution and explaining that they simply wanted to observe the heavens, the Mitterlings won the judgment handily. Judge Morton wrote "the court finds that [the defendant's] security light as now established constitutes a private nuisance in that it impacts the usability of plaintiff's observatory."

The judge ordered the defendants to either remove the light, shield it effectively, or provide the Mitterlings access to a switch they could use to turn off the light when using the observatory. The defendants installed a shielded light.

Holding his judgment as eminently fair, Judge Morton ended the order by stating that "the Court notes that each of these remedies also requires the defendants to install no other lights or objects to block use of the observatory." The Mitterlings now have a dark sky for observing whenever they want it.

PUBLIC SCOPE IN HAWAII

How do you bring astronomy to the masses? Transport a telescope to the people, according to William C. Leighty, a businessman and self-styled astronomy promoter in Juneau, Alaska. After developing a user-friendly 16-inch telescope designed for public star parties, Leighty decided to loan his prototype telescope to the Hyatt Regency Hotel in Maui, Hawaii, for one year.

"I wanted to make a statement about how much fun amateur astronomy is by providing a comfortable, convenient way for people to see the cosmos," said Leighty. "A resort hotel at a low latitude with a profoundly transparent and dark sky seemed the most effective place to get people to look at the stars."

"The program will test whether or not this approach is effective for public astronomy education," said Leighty. "I envision a time when many public places like hotels and resorts will include the world of astronomy in their entertainment programs, and it may add large numbers of people to the ranks of amateur astronomers." □



A NEIGHBOR'S GLARING LIGHT peeks out from behind Alan Mitterling's observatory near Warsaw, Indiana. Mitterling took the neighbors to court and forced them to shut it off.

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Headed by some of the world's most distinguished scientists, The Planetary Society provides more than 100,000 members with knowledge and inspiration that sparks their imaginations and keeps them on the cutting edge of space exploration.

U.S. Planetary missions scuttled. New hopes for new missions.

Since 1978, the U.S. has not launched a single mission to the planets—after dozens of historic missions in the preceding two decades. Today, The

Planetary Society is spearheading efforts to renew U.S. commitment to missions awaiting launch: *Galileo*, *Magellan*, *Ulysses* and *Mars Observer*. And we are disseminating information to the American people on the ambitious Soviet *Phobos* mission and on future Soviet Mars exploration. We are also leading the drive for a multinational piloted mission to Mars and new expeditions to other planets. We invite you to join us.

Many membership benefits.

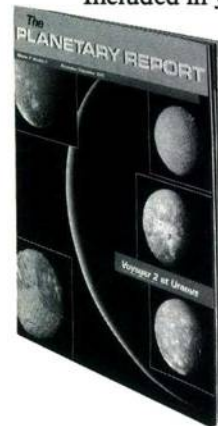
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Co-founders of The Planetary Society: Bruce Murray, Professor of Planetary Sciences, California Institute of Technology (seated left); Carl Sagan, Director, Laboratory for Planetary Studies, Cornell University (seated right); Louis Friedman, Executive Director (standing).

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2080 LX6 (List: \$ 4,400) CALL
 2120 LX6 (List: \$ 6,400) CALL

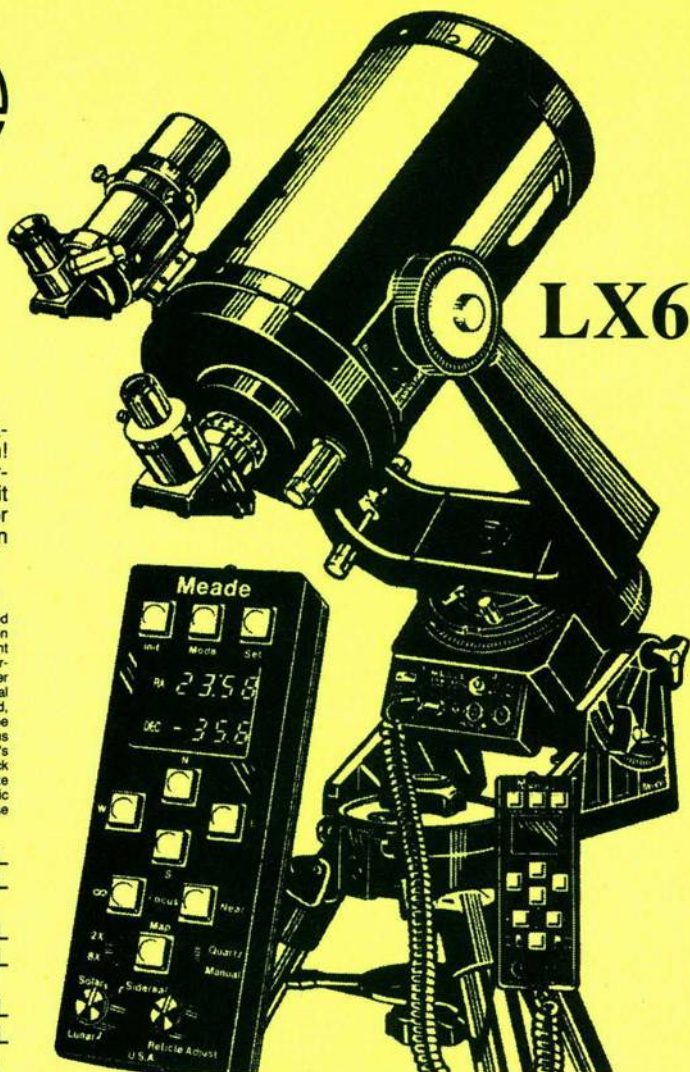
Optional Digital Readout System:

Mod. 9068, for 2080 LX6 (List: \$ 590) CALL
 Mod. 9070, for 2120 LX6 (List: \$ 590) CALL

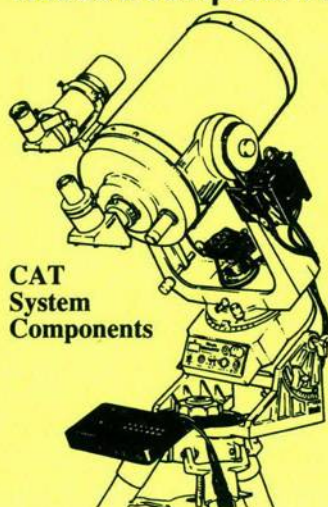
Package: Telescope and Optional Digital Readout System, together:

2080 LX6 with Mod. 9068 (List: \$4,990) CALL
 2120 LX6 with Mod. 9070 (List: \$6,990) CALL

FREE FREIGHT! (UPS Ground) for the LX6's shown above



Meade's Computer-Aided Telescope System

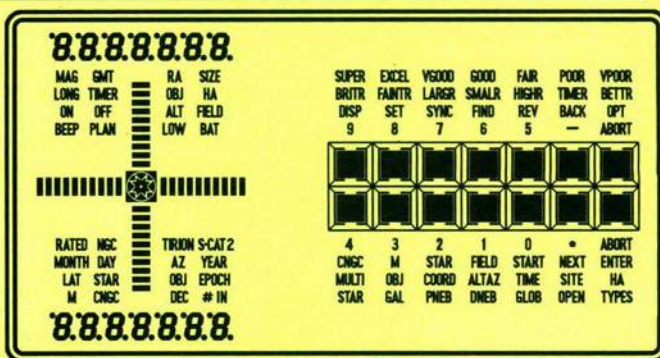


CAT System Components

Meade's Computer-Aided Telescope (the "CAT") system has most of the advantages of a computer-controlled telescope at only a fraction of the cost. Consisting of a specially-designed, high-speed, extremely powerful computer, along with a pair of high-resolution incremental shaft encoders and their associated mounting hardware, drive components and cabling (see general arrangement drawing at left, and panel layout drawing at right), the CAT can readily and quickly direct you to any of the thousands of celestial objects whose coordinates and other descriptive information are permanently stored in its 1Mb plug-in EPROM database, including all of the planets, as well as to any other celestial object of known coordinates (comets, asteroids, quasars, super-novae, etc.). The computer is loaded with extra features and functionality as the panel legends, at right, indicate.

For the computer-literate, there is also a version of the CAT available with an RS-232C port (the "CAT-COM") for connection to a "PC" compatible personal computer. CAT-COM includes four "demonstration" software subroutines, written in BASIC, to show you how to address and control the CAT from your own computer, as well as the necessary RS-232C interconnect cable. The software is supplied on a 5.25" 360Kbys diskette, with backup source-code listings in the instruction manual.

The CAT is available for most fork-mounted Schmidt-Cassegrain telescopes, but has been electronically integrated with the new LX6 series, so that the encoders and the CAT computer plug directly into the drive-base. Consequently, during our introduction of the LX6 series telescopes, we are offering extra savings on packages consisting of an LX6 telescope and one or the other of the CAT systems.



Optional Computer-Aided Telescope (CAT) System:

CAT for 2080 or 2120 LX6 (List: \$1,990) CALL
 CAT-COM for 2080 or 2120 LX6 (List: \$2,290) CALL

Package: Telescope and Optional CAT System, together:

2080 LX6 with CAT (List: \$6,390) CALL
 2080 LX6 with CAT-COM (List: \$6,690) CALL
 2120 LX6 with CAT (List: \$8,390) CALL
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 Hardcopy Listing of CAT Database (List: \$ 60) CALL

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Astronomy

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optional and
accessory
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These scopes' wide, bright, highly corrected fields of view ("rich"-fields) and "fast" focal ratios make them ideal for both deep space visual observing and prime focus astrophotography. Easy and convenient to transport and use because of their "fork"-type equatorial mounts, they are excellent all-around scopes for those just starting in astronomy, as well as for experienced astrophotographers. Their 1.25"/2.00" focuser not only permit the use of the greatest variety of eyepieces, but also allow the fullest illumination of the film-plane during photography. 6" scope available with or without Mod. 788 motor drive. 8" scope available with Mod. 788 motor drive, or "LX3" quartz-synchronized micro-electronic drive system for maximum accuracy and precision. All are available with or without "MCOG" (multi-coated optics group) optical coatings, which enhance brightness and contrast of visual and photographic images.

Specs: Basic MTS-SN6: Complete 6" A, 1/5 Schmidt-Newtonian telescope tube assembly (152.4mm aperture, 762mm focal length); 2" helioid focuser, with 1.25" adapter; 25mm (30x) MA eyepiece, 1.25" barrel; rugged dual-fork equatorial astronomical mount with graduated setting circles, latitude adjustment, and latitude scale; pipe-pier stand with quick-mount tri-legs; dust cover; instruction manual; limited lifetime warranty.

Ask about our special finderscope
& barlow Accessory Packages for
these MTS Schmidt-Newtonians

Specs: Basic MTS-SN8: Complete 8" A, 1/4 Schmidt-Newtonian telescope tube assembly (203.2mm aperture, 812.8mm focal length); 2" helioid focuser, with 1.25" adapter; 25mm (32.5x) MA eyepiece, 1.25" barrel; rugged dual-fork equatorial astronomical mount with graduated setting circles, latitude adjustment, and latitude scale; Mod. 788 worm-gear drive, 115Vac 60Hz; pipe-pier stand with quick-mount tri-legs; dust cover; instruction manual; limited lifetime warranty.

MTS-SN6		(List: \$ 1,050)		CALL
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MTS-SN6, 788 MtrDrv		(List: \$ 1,200)		CALL
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Meade's MTS Schmidt-Cassegrains Best-Value All-Around Performers!

Shown:
MTS-SC10 with
optional and
accessory
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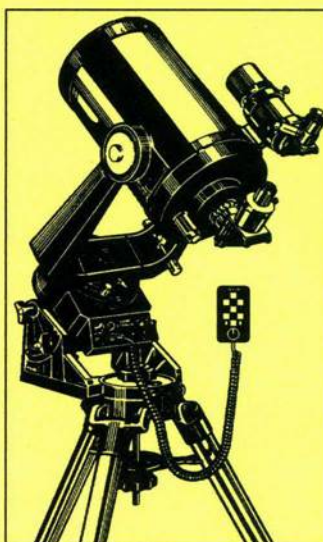
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FREIGHT!

These scopes' "general-purpose" f/10 focal ratios and modest prices make them the best-value "all-purpose", "do-everything" scopes available. Optically capable of delivering exquisite views and photographs of almost all types of astronomical objects "as-is", they may nevertheless be extended to extremely "fast" effective focal ratios and correspondingly wide fields of view by means of telecompressor accessories, or to extremely high power, narrow-field lunar, planetary and multiple-star work by means of Barlow lens accessories. Each scope is available with or without "MCOG" (multi-coated optics group) optical coatings, which enhance brightness and contrast of visual and photographic images, and with either the Mod. 788 motor drive, or the "LX3" quartz-synchronized micro-electronic drive system for maximum accuracy and precision. Compact, portable, easy to use visually and photographically, and with Meade's high-quality optics, the MTS Schmidt-Cassegrains are an extraordinary value in astronomical telescopes.

Specs: Basic MTS-SC8 and MTS-SC10: Complete 8" A (SC8) or 10" A (SC10) f/10 Schmidt-Cassegrain telescope tube assembly (203.2mm [SC8] or 254mm [SC10] aperture, 2,000mm [SC8] or 2,500mm [SC10] focal length); with certified diffraction-limited optical system; ultra-smooth anti-backlash focus mechanism; 6x30mm (SC8) or 8x50mm (SC10) viewfinder; 1.25" visual accessory holder; 1.25" anti-reflection coated prism-type star diagonal; 25mm (80x [SC8] or 100x [SC10]) MA eyepiece, 1.25" barrel; rugged dual-fork equatorial astronomical mount with graduated setting circles, latitude adjustment, and latitude scale; Mod. 788 worm-gear drive, 115Vac 60Hz; pipe-pier stand with quick-mount tri-legs; dust covers for optical apertures; instruction manual; limited lifetime warranty.

MTS-SC8, 788 MtrDrv	.....	(List: \$ 1,800)	.....	CALL
MTS-SC8, 788 MtrDrv, MCOG	.....	(List: \$ 1,890)	.....	CALL
MTS-SC8, LX3 MtrDrv	.....	(List: \$ 2,150)	.....	CALL
MTS-SC8, LX3 MtrDrv, MCOG	.....	(List: \$ 2,240)	.....	CALL
MTS-SC10, 788 MtrDrv	.....	(List: \$ 2,780)	.....	CALL
MTS-SC10, 788 MtrDrv, MCOG	.....	(List: \$ 2,950)	.....	CALL
MTS-SC10, LX3 MtrDrv		(List: \$ 3,180)		CALL
MTS-SC10, LX3 MtrDrv, MCOG		(List: \$ 3,350)		CALL

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Meade's LX5's

Fully equal to LX6's in terms of their standard equipment, they come complete with quartz-lock microelectronic pulse motor drive, sophisticated hand control unit with photographic drive correction functions built-in, 2.00" star diagonal for advanced, premium-grade eyepieces, & giant 9x60mm finder-scope!

Specs: 2080/LX5 and 2120/LX5: Complete 8" A (2080/LX5) or 10" A (2120/LX5) f/10 Schmidt-Cassegrain telescope tube assembly (203.2mm or 254mm aperture, 2,000mm or 2,500mm focal length); with certified diffraction-limited optical system; MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity mirrors; ultra-smooth anti-backlash focus mechanism; giant 9x60mm illuminated-reticle polar-alignment viewfinder with quick-disconnect mounting bracket; 2.00" mirror-type star diagonal, with 1/10 wave multi-coated mirror and adapter for 1.25" eyepieces; Series 4000 28mm Super Plossl eyepiece, 1.25" (77x or 96x); rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; digital quartz micro-electronic sidereal-rate pulse-motor drive system and ultra-precision "LX" worm-drive gearing built into telescope drive base; Power Control Panel (also built into drive base) with controls, indicators and connectors for various accessory and auxiliary electronic equipment; Electronic Command Center hand-control unit; 115Vac 60Hz AC power adapter with 25 ft. cord; DC battery-pack (batteries not included) with 4 ft. cord; 25 ft. DC power cord with automobile cigarette-lighter plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth (polar-alignment adjustments), latitude scale, bubble level, magnetic compass (and no-tool knob set on 8" scope only); ultra-rigid adjustable-height Field Tripod; dust covers for optical apertures; foam-lined carrying case for scope-tube/fork-mount/drive-base assembly; audio cassette instructions; instruction manual; limited lifetime warranty.

2080/LX5, MCOG, Wedge, Tripod (as above)	..	(List: \$ 3,800)	.....	CALL
2120/LX5, MCOG, Wedge, Tripod (as above)	..	(List: \$ 5,400)	.....	CALL

FREE FREIGHT! (UPS Ground) for the LX5's above

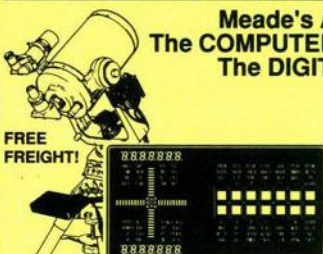
Meade's LX3's - Still Going STRONG!

Specs: 2080/LX3 and 2120/LX3: Complete 8" A (2080/LX3) or 10" A (2120/LX3) f/10 Schmidt-Cassegrain telescope tube assembly (203.2mm or 254mm aperture, 2,000mm or 2,500mm focal length); with certified diffraction-limited optical system; MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity (multi-layer over-coated) mirrors; ultra-smooth anti-backlash focus mechanism; large 8x50mm viewfinder; 1.25" visual back (eyepiece holder); 1.25" prism-type star diagonal, anti-reflection coated; 25mm (80x or 100x) MA eyepiece, 1.25" barrel; rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; quartz micro-electronic sidereal-rate drive system and ultra-precision "LX" worm-drive gearing built into telescope drive base; Power Control Panel (also built into drive base) with controls, indicators and connectors for various accessory and auxiliary electronic equipment; Electronic Command Center hand-control unit (10" 2120/LX3 only); 115Vac 60Hz AC power adapter with 25 ft. cord; 25 ft. DC power cord w/cigarette-lighter plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth (polar-alignment adjustments), latitude scale, bubble level and magnetic compass (and no-tool knob set on 8" scope only); ultra-rigid adjustable-height Field Tripod; dust covers for optical apertures; foam-lined carrying case for scope-tube/fork-mount/drive-base assembly; instruction manual; limited lifetime warranty.

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Meade's Advanced Electronic Systems The COMPUTER-AIDED TELESCOPE System The DIGITAL SETTING CIRCLE System



Meade's "CAT" and "DSC" Systems enhance your observing pleasure by virtually eliminating the difficulties of "finding". Sophisticated micro-computer technology and software make it possible! The CAT System (at left), contains an internal catalog of over 7,500 astronomical objects. The DSC System provides precise, digital coordinate readout too, but without the internal catalog. Both systems are easy, built on retrofits - no drilling or tapping required. A variant of the CAT ("CAT-COM") can communicate with a PC-type computer (see opposite page for details). Package pricing is available when either System is purchased at the same time as its telescope (not for MTS).

Individual System Pricing:				
DSC Sys., for 2080, 2120, C8 or C11	.....	(List: \$ 700)	.....	CALL
CAT Sys., for 2080, 2120, C8 or C11	.....	(List: \$ 1,990)	.....	CALL
CAT-COM, for 2080, 2120, C8 or C11	.....	(List: \$ 2,290)	.....	CALL
Package Pricing (Electronics System purchased at same time as its telescope):				
DSC Sys., for 2080, 2120, C8 or C11	.....	(List: \$ 700)	.....	CALL
CAT Sys., for 2080, 2120, C8 or C11		(List: \$ 1,990)		CALL
CAT-COM, for 2080, 2120, C8 or C11		(List: \$ 2,290)		CALL

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One Small Step

Twenty years ago, men first set foot on the surface of the Moon and declared "We came in peace for all mankind." ASTRONOMY celebrates this achievement with a special issue dedicated to the human presence on the Moon.

The future now promises a return to the Moon — this time to establish permanent bases and scientific outposts. What will the *next* twenty years bring? We can only begin to imagine the coming era of lunar exploration, when geologists will spend weeks roving the surface and giant radio telescopes will span craters as they probe the universe.

Whatever the exact outcome — and however long it takes — it is already clear that Neil Armstrong's "one small step" into history was just the beginning of a long road that leads ever outward.





20TH ANNIVERSARY OF APOLLO 11

“I’m at the Foot of the Ladder . . .”

It was truly an incredible journey. From bone-jarring takeoff to splashdown, the twenty-seven men who went to the Moon experienced something no one else ever has. Here they tell us what it was like.
by Harry Hurt III





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A Morgan Entrekin Book.

APOLLO 11: The seismometer Buzz Aldrin is erecting showed the Moon is geologically quiet and helped scientists accurately picture its internal structure.

The Public Affairs Officer anxiously watched the ticking of the countdown clock.

"We're coming up on the 60-second mark. We're at T minus 60 seconds and counting. We are GO for a mission to the Moon at this time. . . ."

At T minus 12 seconds, the swing arms bracing the Saturn 5 started to pull away, and the ignition sequence began.

At T minus 8.9 seconds, the first fireballs burst out the end of the trench. But because the booster was still locked tightly to the launch pad by four giant metal hold-down clamps, it did not move. Instead, it continued steadily building thrust.

"Three!"

"Two!"

"Launch commit."

"Zero!"

At that instant, all four hold-down clamps flopped back simultaneously. Seeing the clamps release, the PAO cried, "Liftoff! We have a liftoff!"

The three crewmen atop the 360-foot-tall Saturn 5 could not share this view because they had no television monitors on board. Insulated in their "Moon cocoons," they couldn't even hear the rocket's full roar. But all three could feel the bone-jarring quake of liftoff and the gut-wrenching low-frequency shock waves of the booster. And as *Apollo 16's* Ken Mattingly reports, "It feels just like it sounds."

Apollo 17's Jack Schmitt adds that the sound of the launch made it feel violent. "The low-frequency vibration is the unusual thing that you'll never get off the television. Some of the films of the crowd watching the launch show them breathing very deeply. It's that low-frequency sound that's moving your innards, your tie and your blouse. That's what makes it an emotional experience even for the viewers."

The trans-lunar injection (TLI) usually began about two-and-a-half hours after lift off. The three crewmen were usually making their second orbit over the Pacific Ocean. Like staging and every other engine burn during the mission, TLI was always announced by a professionally matter-of-fact exchange between Houston and the astronauts.

"You are GO for TLI," rasped the CAPCOM.

"Roger," replied the command module pilot.

"Thank you."

As *Apollo 11's* Mike Collins observes, "There ought to be more to it."

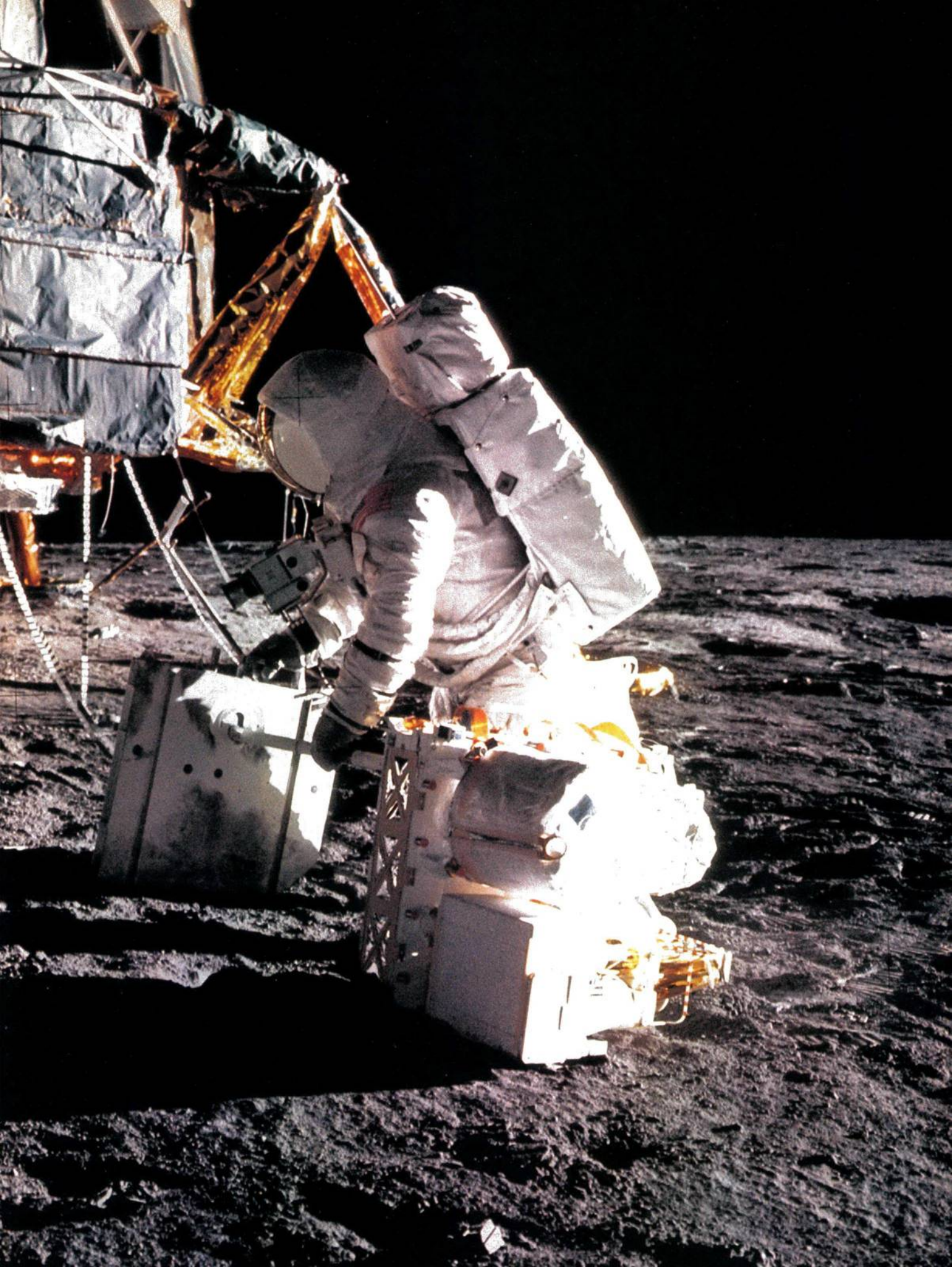
The three astronauts realized that TLI was not just another engine burn, but the one that would enable them to set sail for the Moon.

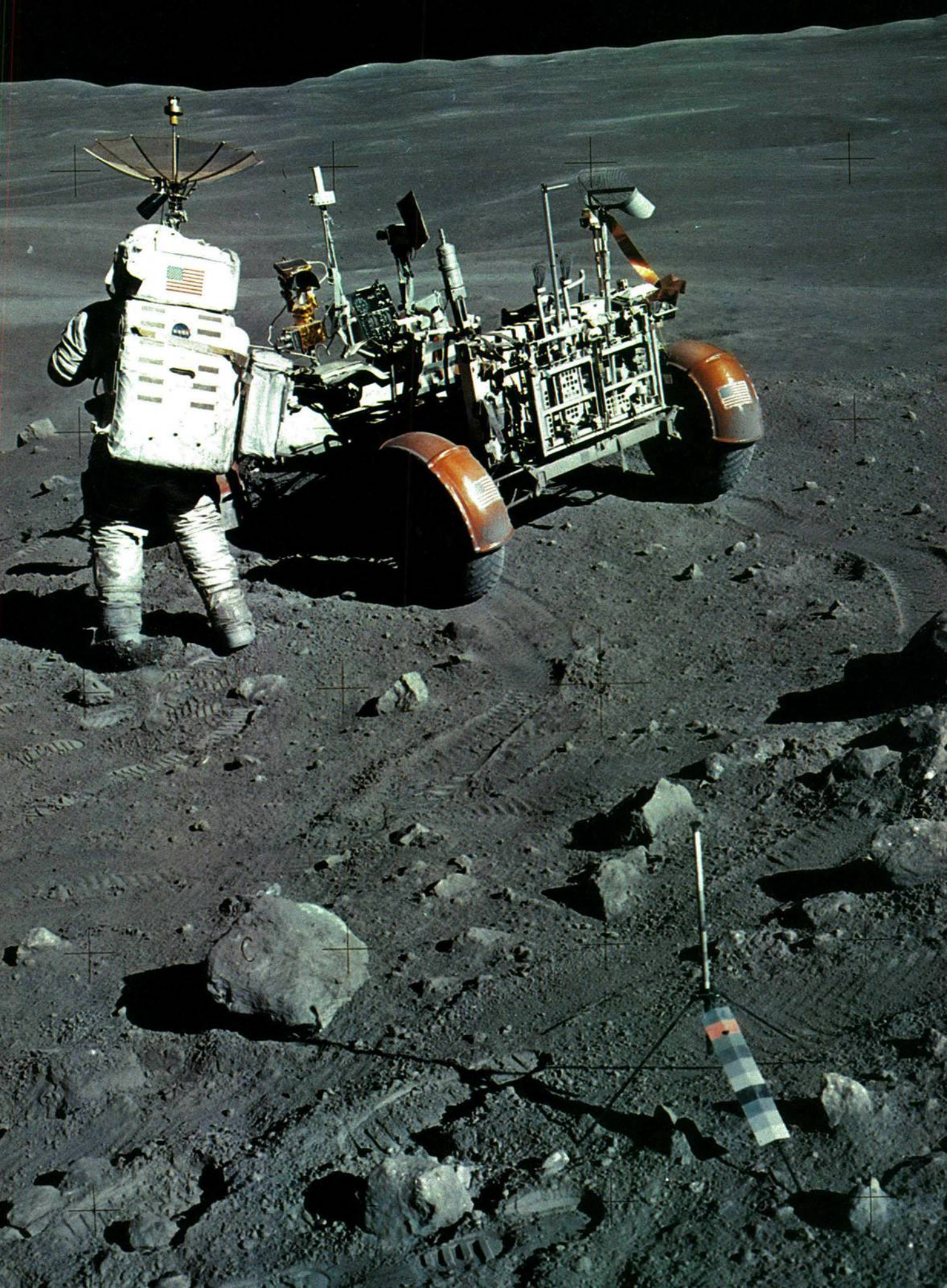
The TLI burn was often, in the words of *Apollo 11's* Buzz Aldrin, "just a tiny bit rattly," but it was nowhere near as bone-jarring as liftoff. The astronauts felt only about one G from the thrust of the S-IVB third stage, and as the burn progressed, they were treated to some breathtaking visuals.

"I just wish I would have had a camera at that point," exclaims Jim Irwin of *Apollo 15*. "I looked



APOLLO 12: Pete Conrad unloads scientific instruments from the lunar module. They were packed in the form of a barbell for easier carrying.





out my window, and there were all the Hawaiian islands. It was a clear morning on the Pacific and you could see the volcanos of Mauna Loa and Mauna Kea. We're being lifted up majestically, accelerating to 36,000 miles per hour and you see the islands fade, get smaller and smaller."

The TLI burn lasted for 5 minutes and 47 seconds. Then the third-stage engine shut down, the rattling stopped, and the long trans-lunar coast began.

The astronauts were slightly disoriented by the lack of milestones to mark their progress though cis-lunar space. As *Apollo 12*'s Al Bean observes, "One of the things different about a lunar trip is that first you leave the launch pad, then you leave Earth orbit, then about a couple of days later, after just floating along and watching the Earth get smaller, all of a sudden you're at the Moon. The lack of way points made it seem a little magical or mystical. All of a sudden, you just showed up."

Lunar orbit insertion (LOI) was a braking maneuver, the reverse of the trans-lunar injection that blasted the spacecraft out of Earth orbit. LOI was much trickier and much riskier, however, because it always took place as the astronauts rounded the back side of the Moon. As a result, the crew had to get themselves into lunar orbit without the guidance of the ground.

Invariably, there was almost total silence inside the command module as the three crewmen barreled toward the Moon. At the moment of losing radio contact, they were supposed to be a good 300 nautical miles above and to the left of the lunar hemisphere visible from Earth. But due to the increasing pull of lunar gravity and the trajectory of the spacecraft, they appeared to be plunging in a suicide dive toward the lunar surface.

"You're coming in awful fast," recalls *Apollo 12* command module pilot Dick Gordon, "and the Moon is growing — it's visibly getting larger by the minute — and it looks like you're going to run into the middle of the damn thing. You know intellectually that you're not gonna hit it, but what your eyes see and what your intellect tells you are two different things."

"You're drifting in," says Stu Roosa, "and that old Moon is growing magnificently fast, just filling up the window — pale brown, pale gray, turning black. Then you drift into its shadow and turn around the back side. Soon you're in total darkness."

"You make the LOI burn in the dark, and then without any warning you pop into the light and look out the window for your first good close-up view of the Moon. At that point, we were still about 120 miles above the surface, but it looked so close you thought you could just reach out and touch it."

At first sight, all the astronauts found the lunar landscape forbidding. *Apollo 11*'s Mike Collins recalls, "The Sun was hitting the Moon at a very, very shallow angle, and the craters were throwing

very long shadows. The area looked so chopped up and so sharp, I thought, 'My God, there's no way they're going to find a place smooth enough to put the spacecraft down in that kind of terrain. There's just no way.'"

By the end of the fourth day into the flight of *Apollo 11*, as the crew embarked on their seventh orbit around the Moon, the anxiety level inside the spacecraft began to climb. The undocking and separation maneuver was now less than half a day away. The first lunar touchdown itself was only fifteen hours away.

Awakened by the crackle of the radio, Armstrong and Aldrin tumbled out of their hammocks to help Collins fix breakfast. Both were starting to feel the pressure. Armstrong had gotten less than six hours of sleep, Aldrin only five. Despite the fact that they were beginning their fifth day in space and were also veterans of *Gemini* flights, they fumbled with their color-coded food packets like nervous rookies.

The spacecraft slipped behind the Moon for the tenth time, breaking contact with Houston. Aldrin crawled through the access tunnel to the Lunar Module *Eagle*, which had been fully pressurized the day before, and powered up the main control panels. Then he floated back to the Command Module *Columbia*, where he and Armstrong doffed their long johns and began putting on their "Moon cocoons."

"I got as far as my liquid-cooled underwear," Aldrin recalls, "and left to make some initial checks in the LM while Neil took my place in the navigation bay to begin changing. There is only room for one man to change clothes, with another standing by to help pull the long crotch-to-shoulder zipper closed. Both Neil and I were determined to put on our suits as perfectly and comfortably as possible — we were going to be in them for quite some time."

The astronauts prepared for undocking during orbit twelve. Entering *Eagle* and closing the hatch behind them, Armstrong and Aldrin pressurized their suits and cross-checked the LM's guidance platform, the rendezvous radar, the descent propulsion system, and the thrusters used for maneuvers.

"*Apollo 11*, Houston," called CAPCOM Charley Duke as the spacecraft went around to the back side of the Moon. "We're GO for undocking." Collins threw the release switch, and a set of explosive bolts popped *Eagle* away from the command module.

Eagle did a slow pirouette in the silence of the lunar void, extending its four spindly legs and lumpy-headed body like a giant insect bursting from its cocoon. A few minutes later, *Columbia* and *Eagle* sailed around the front side of the Moon, where Houston impatiently demanded to know the results of the undocking maneuver.

"The *Eagle* has wings!" Collins cried.

Eagle, however, was still 60 miles above the lunar surface and only a few yards away from *Columbia*. To descend to the Sea of Tranquility, the astronauts had to execute three equally crucial and difficult maneuvers.

First, Collins fired the thrusters of the service module for a few quick seconds. That pushed *Columbia* far enough away from *Eagle* for Armstrong and Aldrin to begin the two-step descent procedure.

They knew they could not simply trust their fate

APOLLO 16: Near South Ray crater, Charley Duke bags a rock. The rover, used on *Apollo 15* to 17, greatly extended the area explored.

to *Eagle's* automatic guidance system. Although the crew had to rely on the on-board computer to calculate the rapidly changing altitude, attitude, velocity, and fuel consumption figures in the initial stages of the descent, Armstrong would have to assume manual control at 500 feet altitude, perhaps even sooner. As Aldrin remarked before liftoff, "The computer isn't going to dodge boulders for you."

Eagle disappeared behind the Moon, then at Armstrong's command, the descent engine fired and started the feet-first plunge toward the surface. A few minutes later, and due to arrive on the Sea of Tranquility in just 12 minutes, Armstrong and Aldrin were 50,000 feet above the lunar surface with a forward velocity of 3,000 miles per hour. And unbeknownst to them and the ground, they were about to confront a series of last-minute crises.

Four minutes into the descent, *Eagle* rolled over to lock in its landing radar, and the crew found themselves upside down, with "Earth right out our front window," as Aldrin put it.

But just before he lost sight of the lunar surface, Armstrong realized he had a problem. As *Eagle* descended, he had been charting their progress by landmarks, comparing their actual pass over times to those in the flight plan. When a crater called Maske-lyne W appeared in his window 2 seconds sooner than expected, he knew something was wrong. Two seconds translated into 2 miles off course.

"Our position checks downrange show us a little long," Armstrong reported.

"Roger, we confirm," replied Charley Duke.

The matter-of-fact exchange belied the gravity of the error. The spacecraft was diving toward the surface 15 miles per hour faster than planned. Mission rules said that if the velocity increased another 8 miles per hour, the astronauts would have to abort the landing. As *Eagle* dropped lower, Houston decided the error would remain in bounds and allowed the landing to continue.

Then the LM's computer flashed an unexpected warning signal.

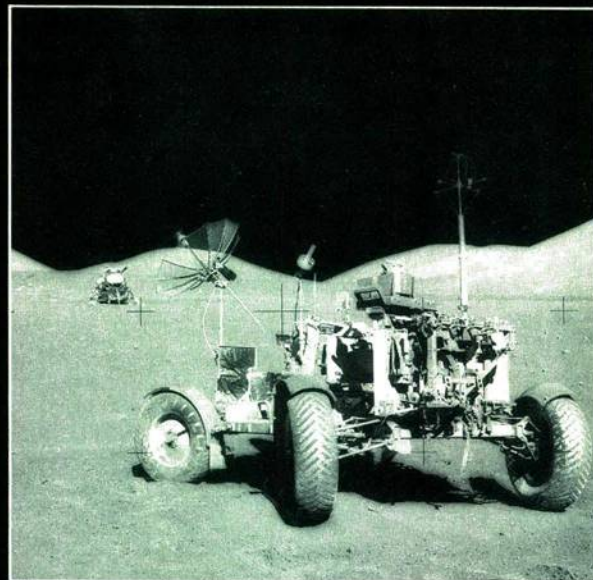
"Program alarm," rasped Aldrin. "It's a 1202."

Thirty seconds passed while Mission Control sought to identify it. "Give me a reading on that alarm," Aldrin demanded.

The 1202 alarm signified "executive overflow" — the computer was being taxed beyond capacity. The cause, however, turned out to be nothing very esoteric: The rendezvous radar had been left on and the computer was attempting to locate a touchdown site on the Sea of Tranquility at the same time as it was trying to plot a course back to *Columbia*. Control told the crew to ignore the alarm.

A little over eight minutes into the descent, *Eagle* reached 7,000 feet and swung upright with its landing legs down. The braking thrust of the descent engine had reduced the velocity to about 60 miles per hour and the exhaust nozzle now pointed down toward the lunar surface. But according to the mis-

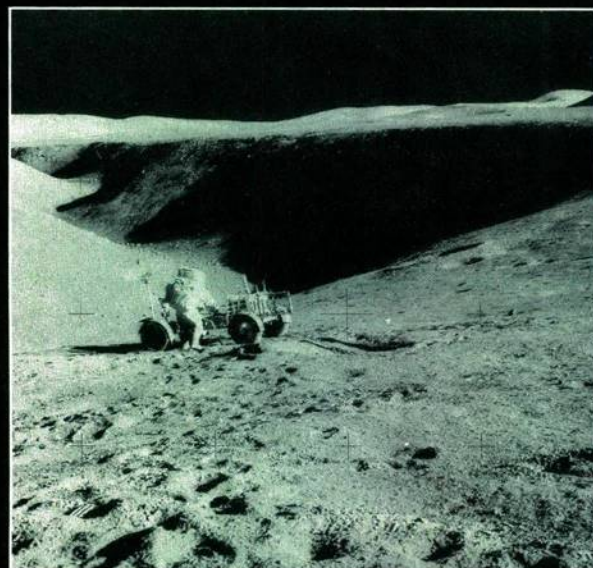
APOLLO ALBUM: Living on the Moon posed few problems once the astronauts learned slightly different work habits. Most enjoyed one-sixth G.



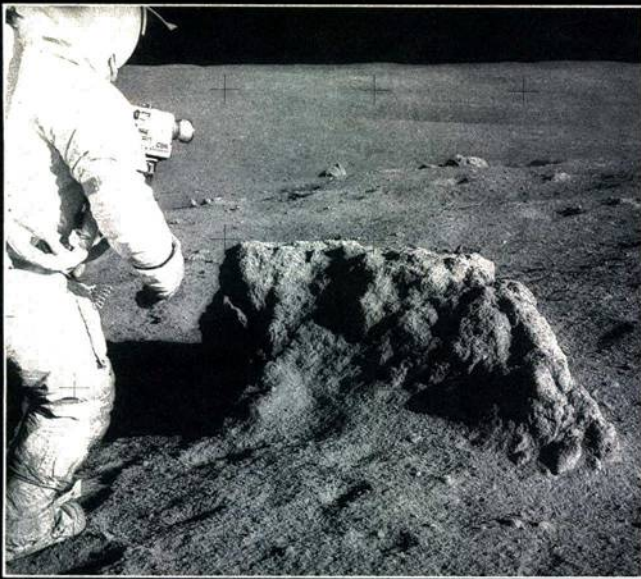
APOLLO 17: Rover and Challenger at Taurus-Littrow.



APOLLO 12: Alan Bean doing the lunar shuffle.



APOLLO 15: Jim Irwin unpacks at Hadley Rille.



APOLLO 14: An outcrop intrigues Alan Shepard.



APOLLO 15: Jim Irwin scoops a sample near the Apennines.



APOLLO 17: At Van Serg crater Gene Cernan tests a rocky outcrop.



APOLLO 12: Alan Bean examines *Surveyor 3*.



APOLLO 16: North Ray crater ejecta dwarfs John Young.



APOLLO 15: The Sun beats down on rolling hills and LM.

sion rules, they had to touch down in less than six minutes or hit the abort handle.

"*Eagle*, Houston. You are GO for landing."

Then at 2,500 feet, *Eagle's* computer registered a second program alarm.

"1201," barked Aldrin.

Houston determined that this indicated an overload similar to the earlier one and gave the GO to proceed. In the meantime, as *Eagle* passed the 1,000-foot mark, the astronauts appeared to be plummeting toward a large crater full of jagged boulders. Armstrong later admitted, "I was surprised by the size of those boulders. Some were as big as small motor cars. And it seemed we were coming up on them pretty fast. Of course, the clock runs at about triple speed in such a situation."

When Armstrong took over control at 500 feet, he could not decide what to do. He made the LM pitch forward so he could "skim over the top of the boulder field." But this extended the approach trajectory. The spacecraft was now at least four miles off course. And it was rapidly running out of fuel.

"I changed my mind a couple of times again, looking for a parking place," Armstrong recalls. "Something would look good, and then as we got closer, it really wasn't good. Finally we found an area ringed on one side by fairly good-sized craters and on the other side by a boulder field. It was about the size of a big house lot, but it looked satisfactory. I was quite concerned about the fuel level. We had to get on the surface very soon or fire the ascent engine and abort."

At 200 feet, he jerked the LM back into the upright position required for landing.

"Sixty seconds," warned CAPCOM Charley Duke, indicating one minute of descent fuel was left.

"Forty feet," Aldrin reported, "down two and one half."

Eagle drifted into the darkness of its own shadow, and quickly became engulfed in an enormous cloud of dust kicked up by the exhaust of the descent engine.

By this time, Mission Control had started the countdown for an emergency abort, but the astronauts were already in the "dead man's zone." As Aldrin noted later, "If anything had gone wrong, it would probably have been too late to do anything about it before we impacted with the Moon."

"Thirty seconds," CAPCOM Duke reported.

Eagle now had less than half a minute of fuel.

"Forward drift?" Armstrong asked.

"Yes," Aldrin confirmed, adding a reassuring, "Okay . . ."

Duke started to call out another fuel consumption reading, but chief astronaut Deke Slayton, who had taken the adjacent seat at the CAPCOM's console, cut him off.

"Shut up, Charley," Slayton ordered, "and let 'em land."

Moments later, *Eagle* gently plopped down somewhere on the uncharted western edge of the Sea of Tranquility. According to Aldrin, "The landing was so smooth that I had to check the lights from the touch down sensors to make sure the slight bump I felt was indeed the landing."

"CONTACT LIGHT!" Aldrin exulted.

Then, keeping to the official flight plan, he

immediately began the post-touchdown checklist.

"Okay," Aldrin noted, "Engine STOP. ACA out of detent."

"Got it," Armstrong confirmed.

"Mode control, both AUTO," Aldrin continued.

"Descent engine command override, OFF. Engine arm, OFF. 413 is in."

"We copy you down, *Eagle*," CAPCOM Duke called a few seconds later. There was a pause.

Then Neil Armstrong said:

"Houston, Tranquility Base here. The *Eagle* has landed."

Armstrong and Aldrin expected moonwalk preparations to take about two hours, but they ended up taking twice that long, partly because the exhaust from their backpacks compounded the difficulty of depressurizing the cabin of the LM. Nearly two hours later than anticipated, *Eagle* finally bled off enough cabin pressure for the astronauts to open the hatch.

With Aldrin's help, Armstrong backed through the hatch onto the porch above the ladder. There were now just nine rungs between him and the lunar surface. He activated the television camera (attached to part of the LM) and backed down the ladder, hopping the last three-and-a-half feet to the footpad.

"I'm at the foot of the ladder. . . . The LM footpads are only depressed in the surface about one or two inches. . . . I'm going to step off the LM now. . . ."

At 9:56 p.m. Houston time, Neil Armstrong lifted his right boot off the pad, planted it in the dust of the Sea of Tranquility, and blurted:

"That's one small step for . . . man, one giant leap for mankind."

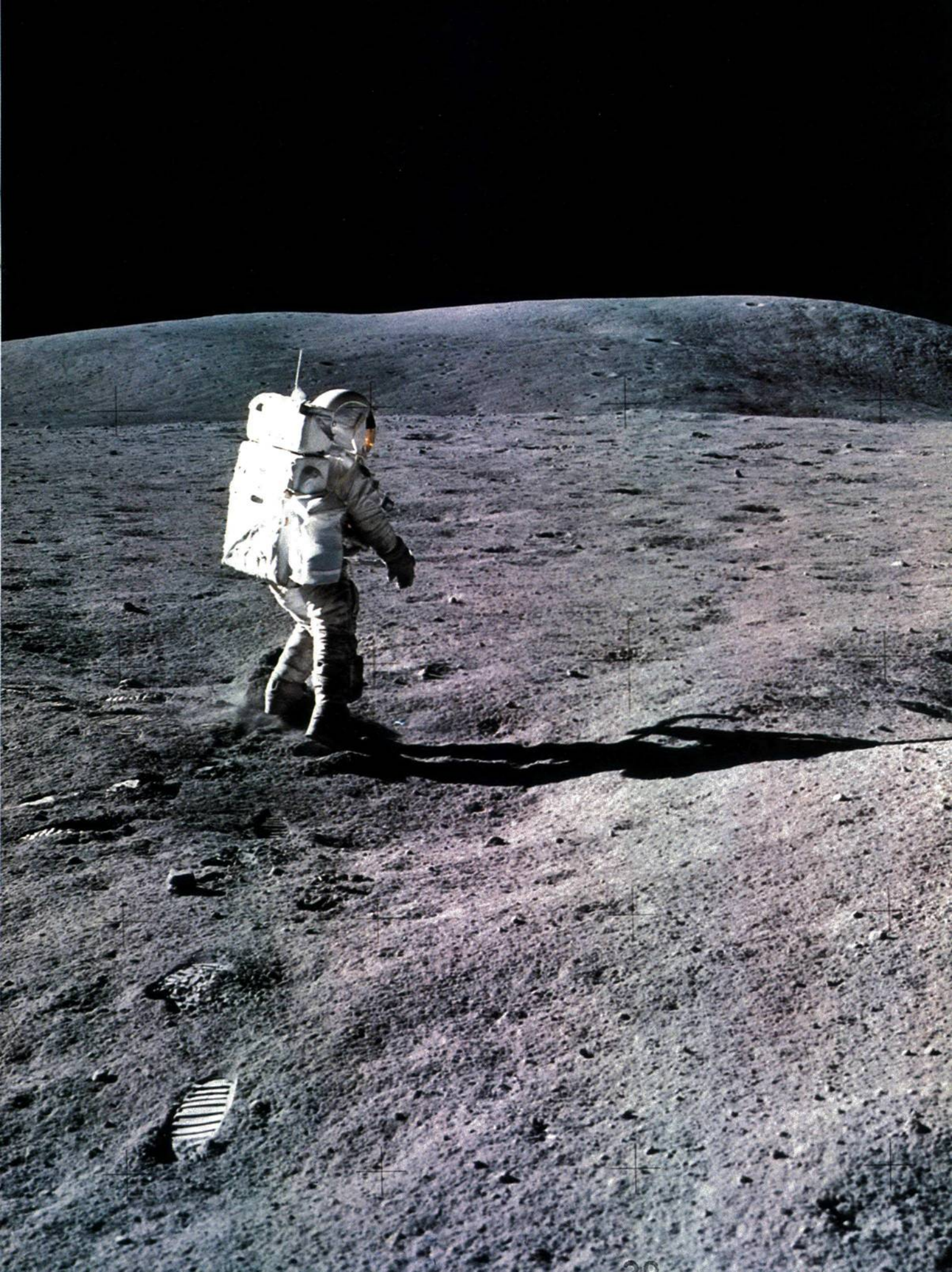
Armstrong's second, third, and fourth steps were a series of short backward shuffles. Then pausing to steady himself at the ladder, he started kicking at the lunar topsoil to test its depth and texture.

"At the surface it's fine and powdery. I can pick it up loosely with my toe. It adheres in fine layers like powdered charcoal to the sole and sides of my boots. I can go in only a fraction of an inch — maybe an eighth of an inch — but I can see the footprints of my boots and the treads in the fine sandy particles."

When Aldrin joined Armstrong on the surface, he called the sight "magnificent desolation." Aldrin later commented, "I immediately looked down at my feet and became intrigued with the peculiar properties of the lunar dust. On the Moon, dust travels exactly and precisely as it goes, and every grain of it lands very nearly the same distance away."

They collected a number of rock samples and erected the flag. They then received a phone call from President Richard Nixon via a special communications link from the White House to Houston to the Moon. Ceremonials over, Armstrong and Aldrin then set up the Early Apollo Scientific Experiments Package. Its three main components were a seismometer to measure any moonquakes, a honey-

APOLLO 16: Charley Duke strolls near Flag crater, where the crew found bedrock unearthed by the impact. Stone Mountain looms on the skyline three miles away.



combed laser retroreflector to let astronomers measure the exact distance between Earth and the Moon, and a solar wind detector, a sheet of aluminum foil designed to trap solar particles.

Armstrong claimed that the lunar surface looked like "a nice place to take a sunbath," and later said, "After landing, we felt very comfortable in the lunar gravity. It was, in fact, in our view preferable both to weightlessness and Earth gravity." Armstrong added his only regret was not being able to spend more time on the Moon. "We had the problem of the five-year-old boy in the candy store. There are just too many interesting things to do."

Aldrin, however, later confessed to experiencing some opposite impressions. As he reported in his post-flight memoir, "I quickly discovered that I felt balanced — comfortably upright — only when I was tilted slightly forward. I also felt a bit disoriented: On Earth when one looks at the horizon, it appears flat. On the Moon, so much smaller than the Earth and quite without high terrain (at least in the Sea of Tranquility), the horizon in all directions visibly curved down away from us."

Aldrin added that jogging or running on the Moon required special precautions. "Earth-bound, I would have stopped my run in just one step — an abrupt halt. I immediately sensed that if I did this on the Moon, I'd be face down in the lunar dust."

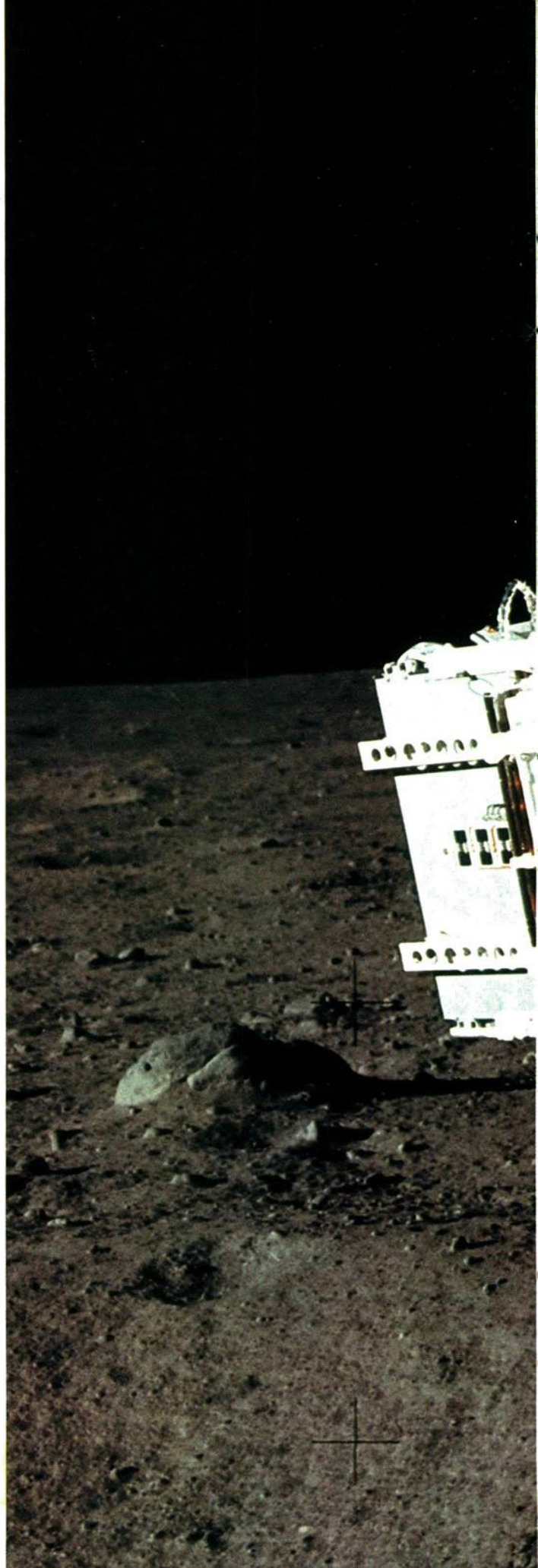
Shortly after the stroke of midnight in Houston, the astronauts were ordered to return to the LM. They later reported that the first thing they noticed when they removed their helmets inside was a peculiar odor. According to Aldrin, "There was a distinct smell to the lunar material — pungent, like gunpowder or spent cap pistols. We had carted a fair amount of lunar dust back inside with us."

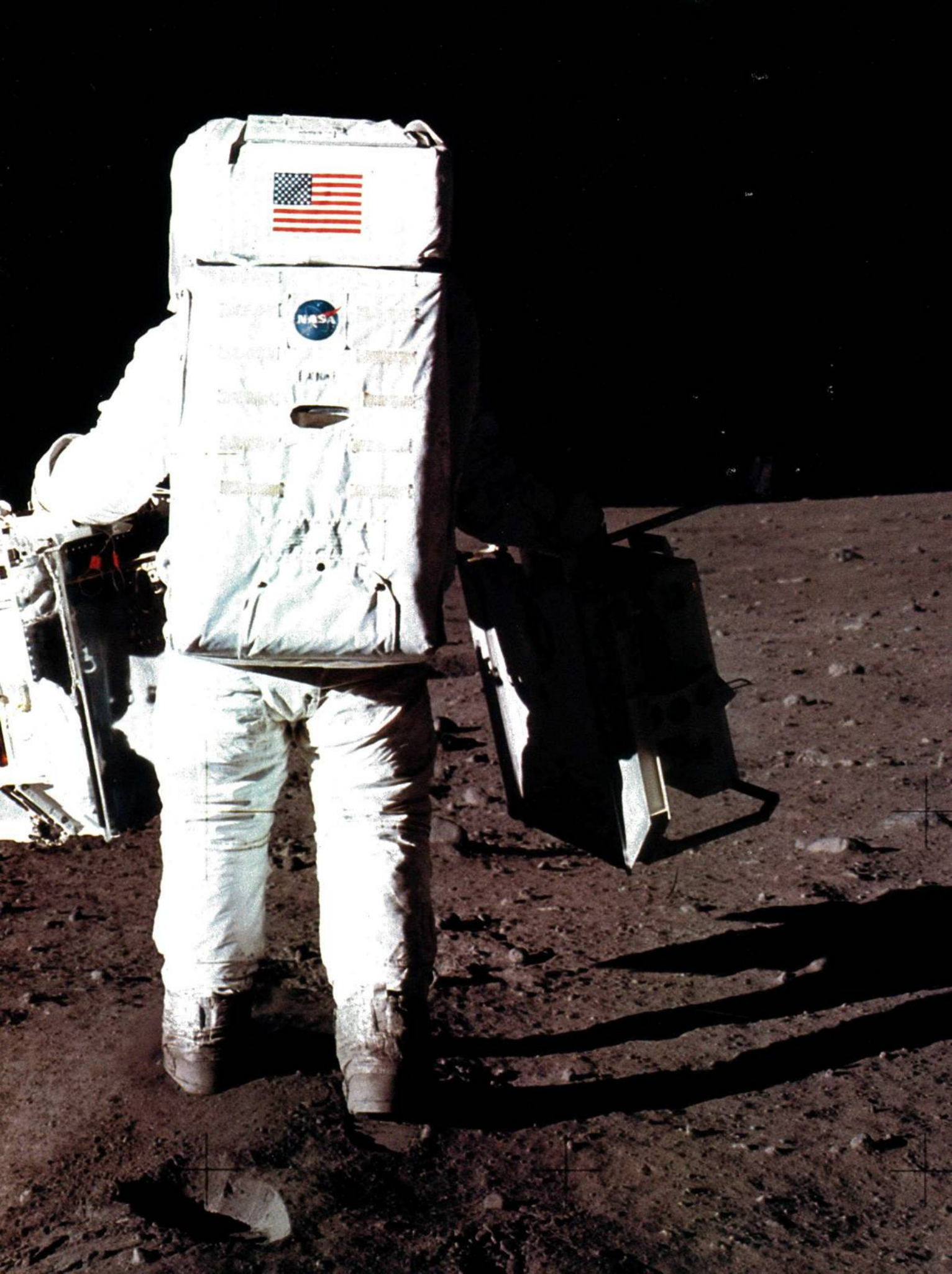
The astronauts spent the next three hours house-keeping and then settled down to sleep. Aldrin tried to curl up on the floor of the LM, only to discover that he was both too elated and too cold to sleep. Armstrong rested even more fitfully. Since there was no room for both to lie on the floor, he slung a hammock between the ascent engine cover and a support bar. It was decidedly uncomfortable. It didn't help that he was facing up toward the unshuttered portal at the top of the cabin. Earth was suspended above the window like "a big blue eyeball."

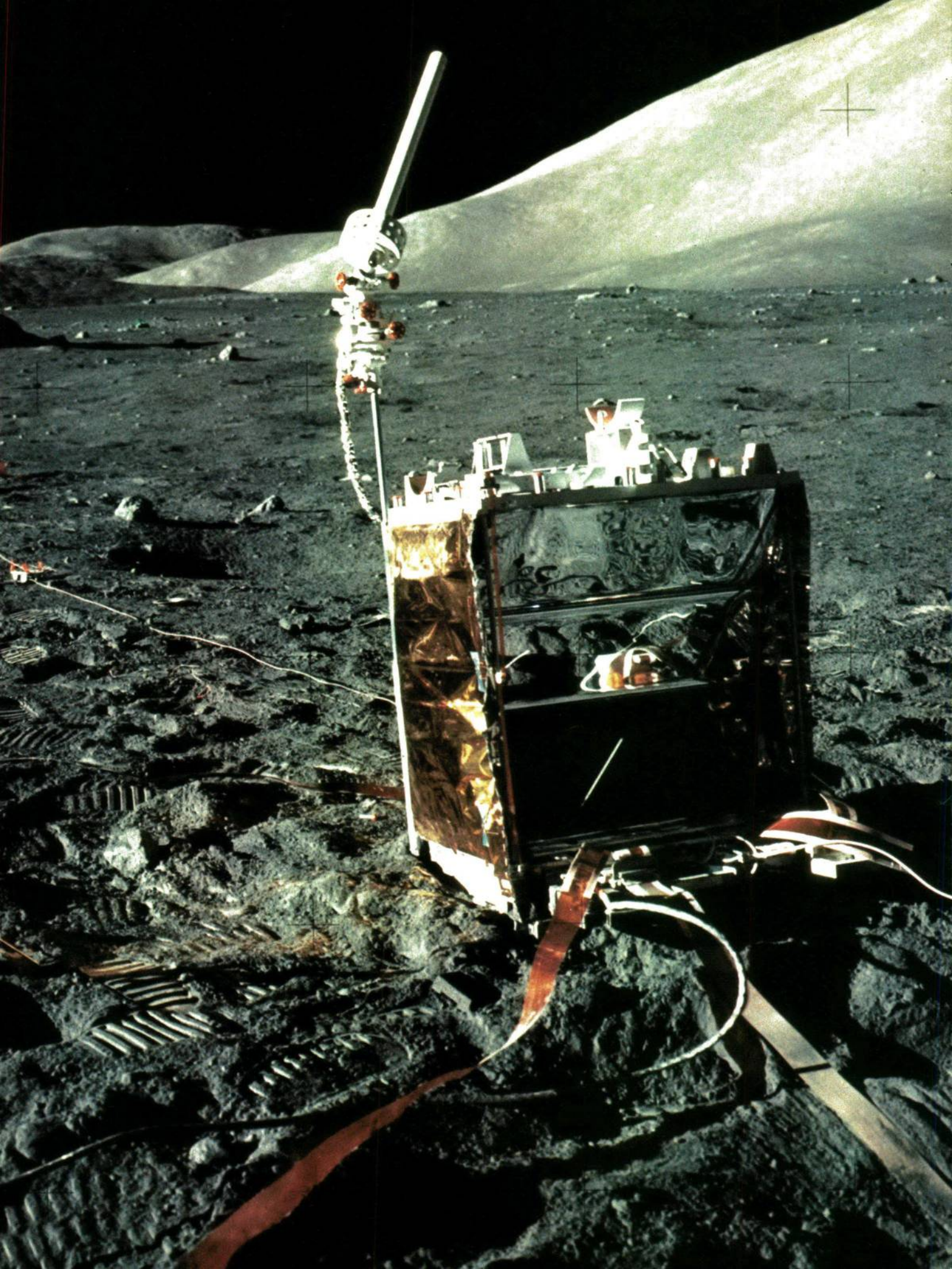
Apollo 11's moonwalk lasted only two and a half hours; other crews spent longer on the Moon and spoke more about their experiences. "Do you know what I feel like, Al?" said *Apollo 12's* Pete Conrad as he bounded over the lunar landscape. "Did you ever see pictures of giraffes running in slow motion? That's just what I feel like." Ed Mitchell on *Apollo 14* bubbled about how he and Alan Shepard were "hopping around like kangaroos."

Apollo 15 carried the first rover vehicle. Dave Scott and Jim Irwin found it provided more than just a physical advantage. "The rover made us feel more at home," Irwin noted, "like we were on Earth,

APOLLO 11: Seismometer in his left hand, retroreflector in his right, Buzz Aldrin skirts the soft lip of a small crater as he walks south from the LM *Eagle*.







where we could just get into our car and drive."

Jack Schmitt of *Apollo 17* remarked, "I had tried to anticipate what it would be like for many years. But there was no way to anticipate standing in the valley of Taurus-Littrow, seeing this brilliantly illuminated landscape with a brighter Sun than anyone had ever stood in before, with a blacker than black sky, and the mountains rising on either side."

"Lift off from the Moon was probably the greatest anxiety of the whole flight," says *Apollo 16's* Charley Duke, "primarily because you really had very little to do during the last 15 minutes of the countdown except sit there and think."

The LM had only one ascent engine. There was no back-up. No emergency escape booster. No second chance. The ascent engine had to light on time and keep burning for just enough time to blast the LM into lunar orbit — or else.

Neil Armstrong and Buzz Aldrin deliberately refused to contemplate what might happen if *Eagle's* ascent engine failed. "That's an unpleasant thing to think about," Armstrong admitted at a pre-launch press conference. "We've chosen not to think about it at the present time."

The crew of *Apollo 12* was nervous, despite the safe return of *Apollo 11*. Commander Pete Conrad tried to ease the mind of his LM pilot, Alan Bean, a rookie.

"Old Al had the fidgy-widgits," Conrad remembers, "and he kept going through his checklist. I said, 'What's the matter, Al? Worried about the engine not lighting?' And he said, 'As a matter of fact, I am.' So I told him he might as well sit back and relax. If the engine didn't fire, we would become the first permanent monument to the U.S. space program erected on the Moon."

"I'm not sure that gave him the comforting, reassuring words he wanted."

Others felt pangs of regret as they prepared to depart. "I was tired and grimy," recalls *Apollo 14's* Ed Mitchell. "But I really regretted climbing up that ladder for the last time because I knew I wouldn't have the chance to come back. The feeling was, 'Take a good look. You're not going to see this again.'"

CAPCOM: Tranquility Base, you're cleared for takeoff.

Aldrin: Roger, understand. We're Number 1 on the runway.

Armstrong: Okay, master arm on.

Aldrin: Nine . . . eight . . . seven . . . six . . . five . . . abort stage . . . engine arm ascent . . . proceed!

A split-second later, the ascent engine ignited and the astronauts felt no more than "maybe half of a G or two-thirds of a G" as they began to rise from the lunar surface.

"There was no time to sightsee," Aldrin reported later. "I was concentrating intently on the computers

and Neil was studying the attitude indicator. But I looked up long enough to see the flag fall over."

"It's like riding in a fast elevator," remembers Alan Bean. "There's a big bang as you separate, but you never hear the main engine because of the vacuum of space. You hear the valves, but you don't hear them firing. All you hear is a little thump-thump-thump kind of sound."

"As we lifted off I could see these sparkling things being blown off the insulation of the descent stage. It looked like the ripples you see when you drop a rock into a pond, this metallic insulation going out in concentric rings."

A little over seven minutes after liftoff, *Eagle's* engine shut down and the craft entered a 10-mile by 45-mile elliptical orbit. When it caught up to the orbiting *Columbia*, the two docked securely and Armstrong and Aldrin rejoined Collins.

Although the astronauts inside the LM had risked their lives on the success of the rendezvous, the command module pilot (who remained in orbit) was almost always the happiest of the three when his comrades finally crawled back into the mothership. That was certainly true of *Apollo 12's* Dick Gordon.

"I've never seen a happier guy in my life," recalls crewmate Al Bean. "He was more happy we got back than we were happy to get back. He was just bananas. He wanted to get us a drink of water. He wanted to fix us some food. He couldn't do enough. It was like returning home to your mother after a twenty-year absence."

All the astronauts eventually had to make the same crucial engine burn to get out of lunar orbit and start the final leg home. This was the trans-Earth injection, or TEI, burn — or as Collins called it, "the get-us-home burn, the save-our-ass burn, the we-don't-want-to-be-a-permanent-Moon-satellite burn."

The TEI burn was never more than three minutes long, but that was powerful enough to make the craft accelerate to lunar escape velocity. As the astronauts were slingshot around the front side of the Moon, they were treated to one of the most thrilling experiences of the entire mission.

"Coming off the Moon is something to behold," recalls *Apollo 14's* Stu Roosa. "After TEI, you have your windows pointed at the Moon and, oh boy, the way you're hauling out of there. . . ."

Apollo 17's Gene Cernan says the sight of a rapidly shrinking Moon inspired an unexpected nostalgia. "Having lived there for three days, the Moon has a familiarity. You say, 'There's home . . . that's where we left the rover. And there's where we explored . . . and there's the mountains and valleys.' And in a sense, it has been a home for you."

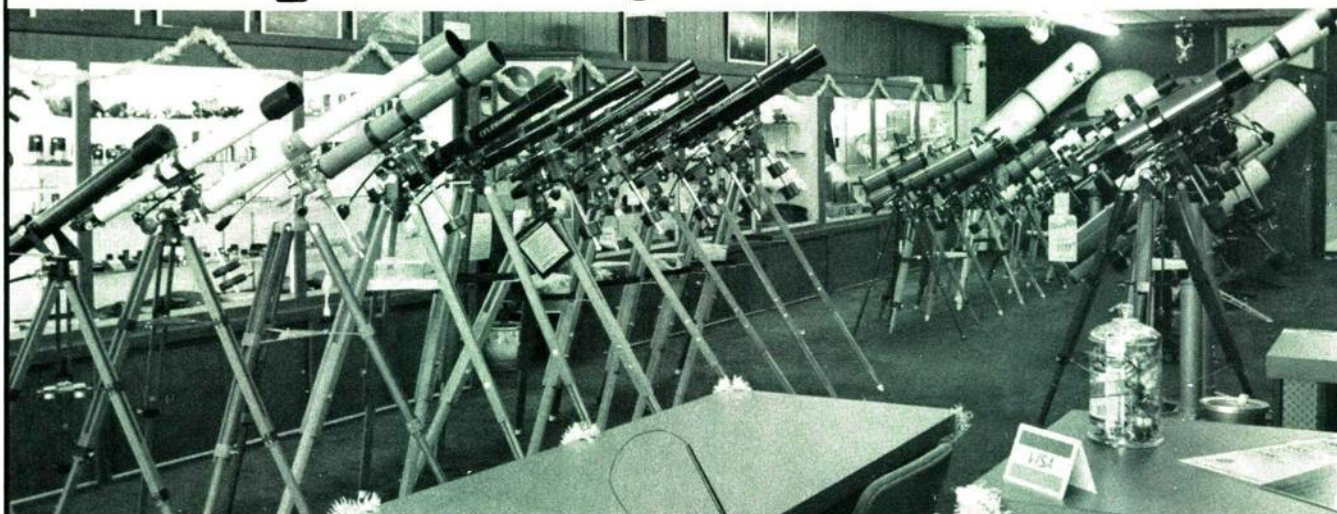
The TEI burn was literally and figuratively the turning point for every Moon landing mission. If the engine failed to light, misfired, or burned too long, the crew would have either remained in lunar orbit or been hurled into space with no hope of being rescued before their oxygen supplies ran out.

"That was the last big hurdle," notes *Apollo 16's* Charley Duke. "After that, to me, it was home free. We still had reentry to go, but for some reason you just knew you were gonna make it. You might not land right on your splashdown site, but you knew you were gonna be all right." □

APOLLO 17: The central station for the instruments radioed data back to Earth long after the crew left. With no erosion, the bootprints would look fresh today.

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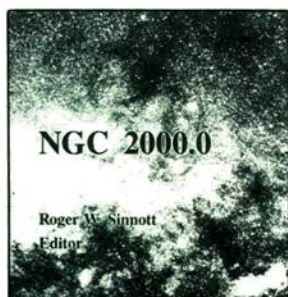
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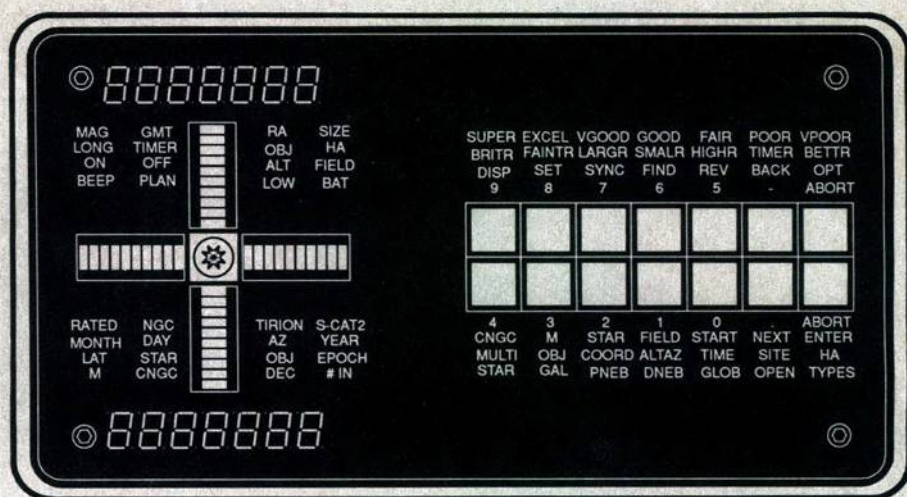
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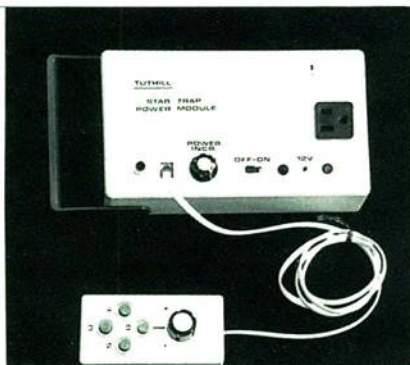
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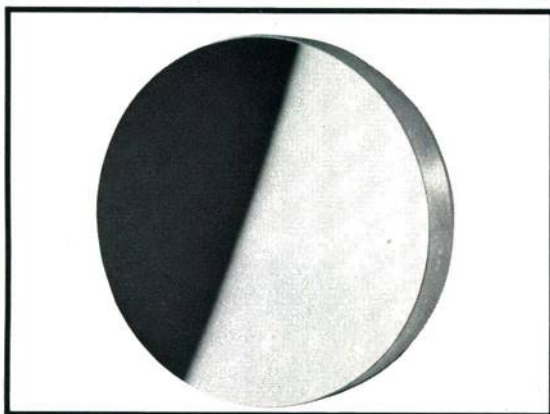


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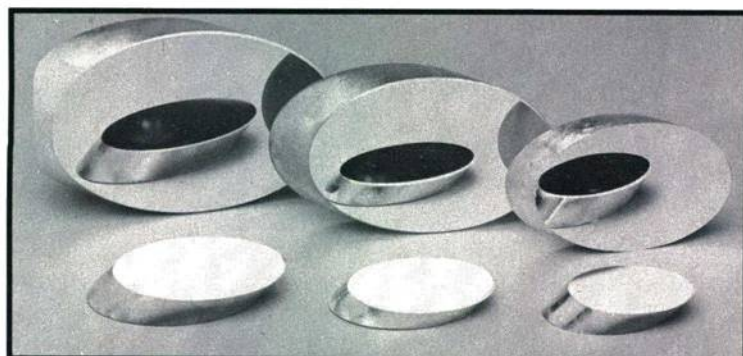
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How Apollo Changed the Moon

The lunar samples and other data returned by Apollo astronauts gave us our first real understanding of the Moon and its history.
by Robert Burnham

When the Earth had just formed, about 4.55 billion years ago, a planetoid a little larger than present-day Mars struck it. Chemical and physical studies of lunar rocks brought back by Apollo show that from this cataclysmic event the Moon was formed. The blow ejected a spray of vaporized rock from both Earth and the impactor. Although most debris fell back to Earth, some of it ringed the planet, Saturn-like, in a sheet.

Over a few tens of thousands of years, the sheet coalesced into lumps that collided and stuck together. As each projectile crashed into the Moon, it generated heat that kept the surface layers molten. Heavier constituents sank to the center, while lighter ones floated up to form a crust.

As the newborn Moon swept up the remaining objects nearby, large impacts blasted out basins and blanketed the lunar landscape with far-flung sheets of melted crust. Of the thousands of basins formed in this period (called the pre-Nectarian), only about thirty are identifiable today.

During pre-Nectarian time, which began when the Moon's crust solidified and ended about 3.9 billion years ago, scientists estimate that basins and ejecta blankets covered over 80 percent of the lunar surface. Samples brought back by *Apollo 15*, *16*, and *17* included very old, heavily shattered rocks — mute testimonials to this period's violence.

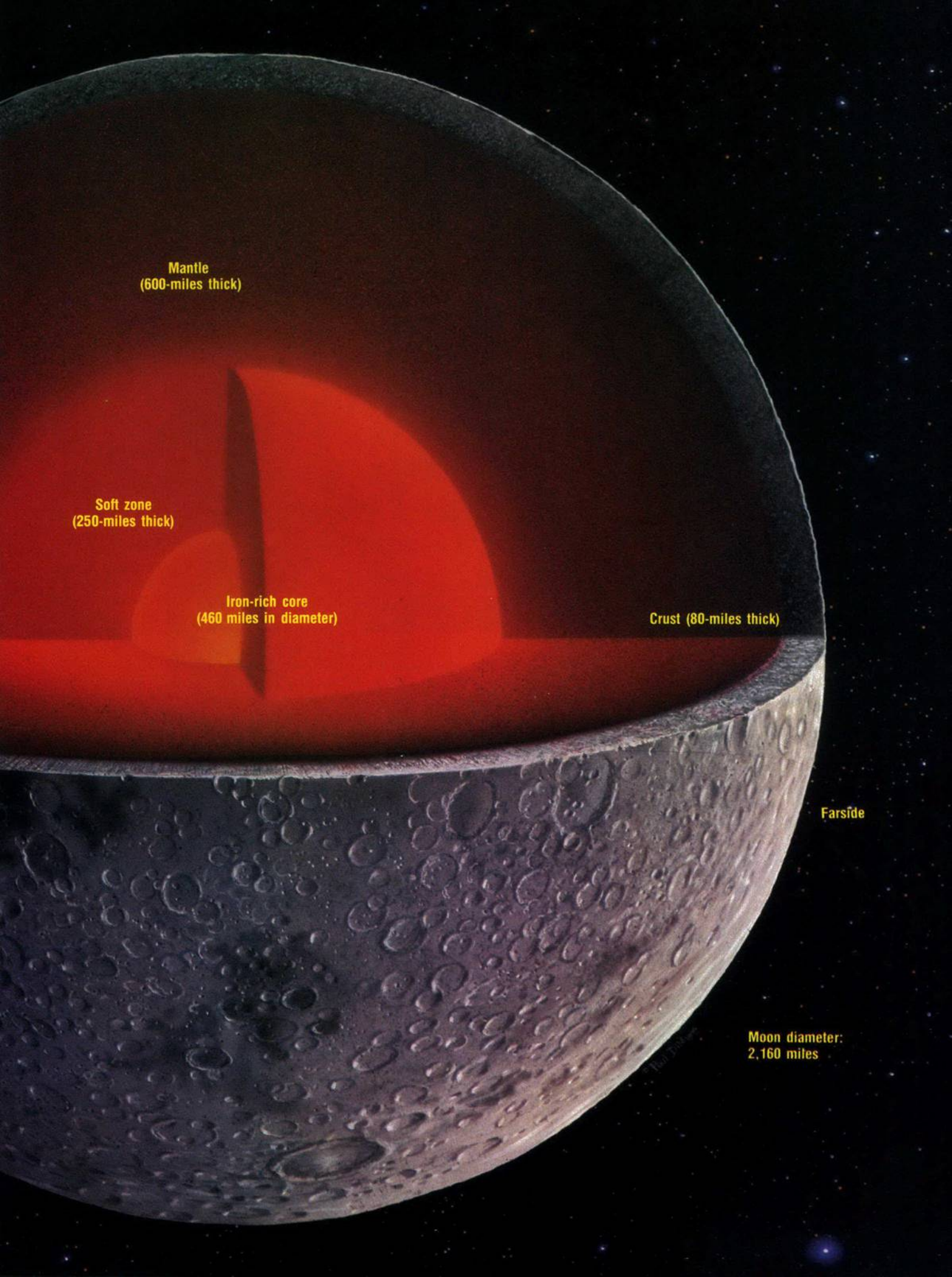
The next period in lunar history, the Nectarian, commenced with the Nectaris basin impact 3.92 billion years ago and ceased just before the Imbrium basin impact 3.85 billion years ago. Nectarian time witnessed impacts creating the wide, deep basins that now hold Mare Nectaris, Mare Serenitatis (3.87 billion years old), and Mare Crisium (3.85 billion years old). Of the other basins gouged out during these 70 million years about a dozen are left, located primarily south of Mare Nectaris, east of Mare Crisium, and on the farside. Nectarian-age craters visible in a small telescope include Clavius, Fracastorius, and Cyrillus. Dates for the basins come from samples returned by *Apollo 16* (Nectaris), *17* (Serenitatis), and the unmanned Soviet *Luna 20* probe (Crisium).

When the asteroid that excavated the Imbrium basin struck 3.85 billion years ago, it marked the start of the Imbrian period, which lunar geologists have subdivided into early and late epochs. The



Crust (40-miles thick)

Nearside



Mantle
(600-miles thick)

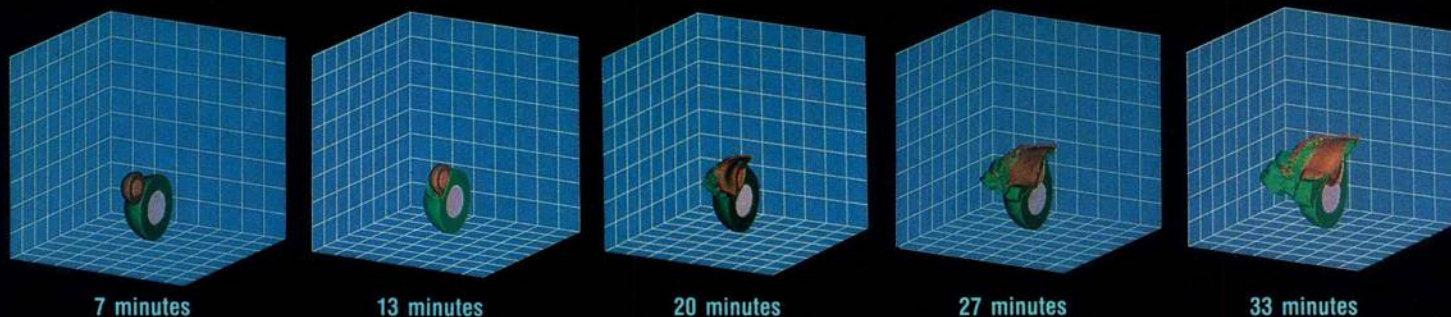
Soft zone
(250-miles thick)

Iron-rich core
(460 miles in diameter)

Crust (80-miles thick)

Farside

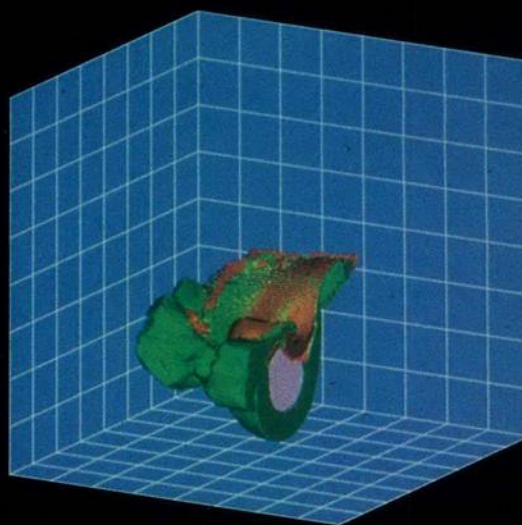
Moon diameter:
2,160 miles



Making a Moon by Impact

These cutaway views, computer simulations by Jay Melosh of the University of Arizona and his colleagues, show a small, Mars-sized object striking the Earth with a glancing blow at 5 miles per second. Most planetary scientists now think this scenario probably occurred shortly after Earth was formed.

Theoretical calculations show that most of the impactor and the ejected Earth material falls back onto Earth again. But a significant amount of the incandescent debris goes into orbit around the Earth and accretes in a few tens of thousands of years into the Moon.



Early Imbrian was brief geologically. Opened by the Imbrium event, which scattered debris over much of the nearside, it closed with the Orientale impact only 50 million years later. In the interval, craters such as Petavius, Arzachel, Ritter, Sabine, and the lava-flooded crater-ring Letronne were formed.

Orientale, the last big basin impact, simultaneously ended the Early Imbrian and formed a watershed in lunar history. When the Late Imbrian period began after the Orientale impact 3.80 billion years ago, a distinct change was coming over the Moon's surface. For the first time, the basaltic lava that had been oozing out of the interior since the beginning now began to accumulate. Prior to this, basin impacts had quickly broken up or buried any lava flows. After Orientale, however, the extruding basalt sheets could fill the miles-deep basins undisturbed.

When you look at "the Man in the Moon," therefore, the dark markings you see are mostly Late Imbrian lava flows. Portions of Oceanus Procellarum filled first, followed by parts of Mare Imbrium; most of Mare Fecunditatis, Mare Nectaris, and Mare Tranquillitatis; and all of Mare Crisium. The lava sheets of Mare Nubium, Mare Humorum, and Mare Orientale also erupted during this period. Telescopic craters formed in the Late Imbrian include Sinus Iridum, Posidonius, Plato, and Archimedes.

Apollo rock samples tell us that the Late Imbrian lasted 600 million years, from 3.8 to 3.2 billion years ago. It was followed by the Eratosthenian period, the longest in lunar history (3.2 billion to 1.2 billion years ago) yet one of the least eventful. During the Eratosthenian period the maria took on their present

appearance, with lava flows erupting mainly in Mare Imbrium, Mare Frigoris, Mare Vaporum, and Oceanus Procellarum. A few prominent craters also appeared — Eratosthenes, Theophilus, Langrenus, Pythagoras, and Aristoteles — and by the end of the Eratosthenian, the Moon looked much as it does today.

The present lunar period is the Copernican, which began about 1.2 billion years ago. By this time, the Moon's internal heat had cooled enough that lava flows were rare. Impact once again became the main process shaping the surface, although at a rate millions of times less than in the Nectarian period. Copernican-age craters include Tycho, Kepler, Aristarchus, Aristillus, Autolycus, and of course Copernicus itself.

We know that the Copernicus impact occurred 810 million years ago because *Apollo 17* brought back rocks thrown out from it. Other crater ages we owe to Apollo are Tycho, 109 million years; West, *Apollo 11*, 100 million; North Ray, *Apollo 16*, 50 million; Cone, *Apollo 14*, 25 million; Shorty, *Apollo 17*, 19 million; and South Ray, *Apollo 16*, 2 million.

The Moon is all but changeless now. Meteorites strike its surface and maintain the finely broken and dusty layer called the regolith. A few weak Moon quakes occur, mainly at apogee and perigee.

But though the lunar world is dead, it is in no sense useless. The Moon preserves a largely intact record of its earliest days. Because that record is more difficult to read everywhere else we look, the Moon that Apollo gave us has truly become the key to the solar system. □

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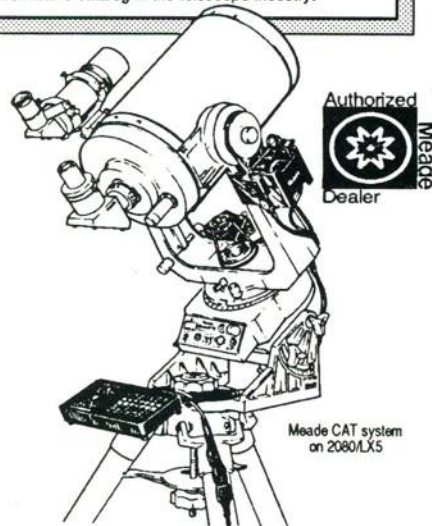
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The "Flame Nebula" NGC 2024 in Orion. Also known as the "Christmas Tree" or the "Tank Trucks" nebula. NGC 2024 is seen best usually with either a LUMICON DEEP-SKY or UHC filter. Photo by Don N. Reiners, 16" f/5, 40 min. using hypered 2415 film and a LUMICON 2" EASY-GUIDER.

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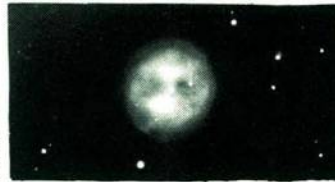
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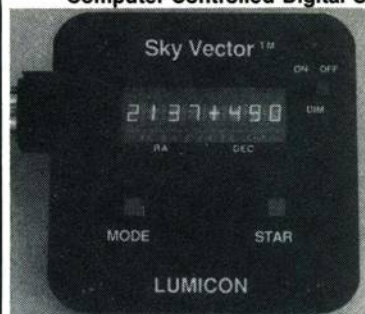
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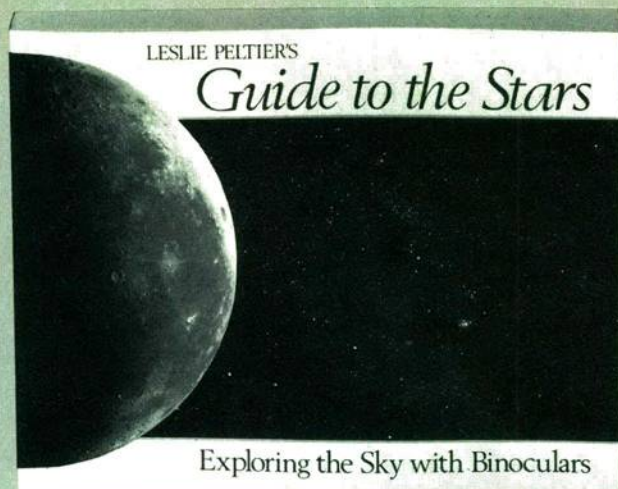


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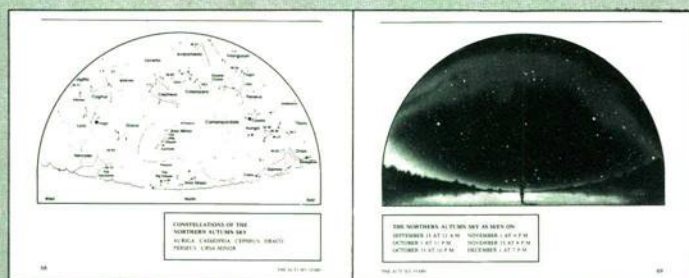
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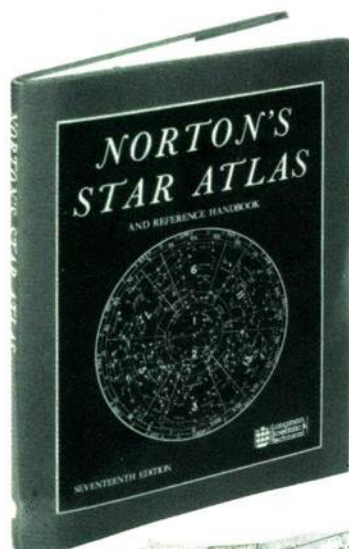
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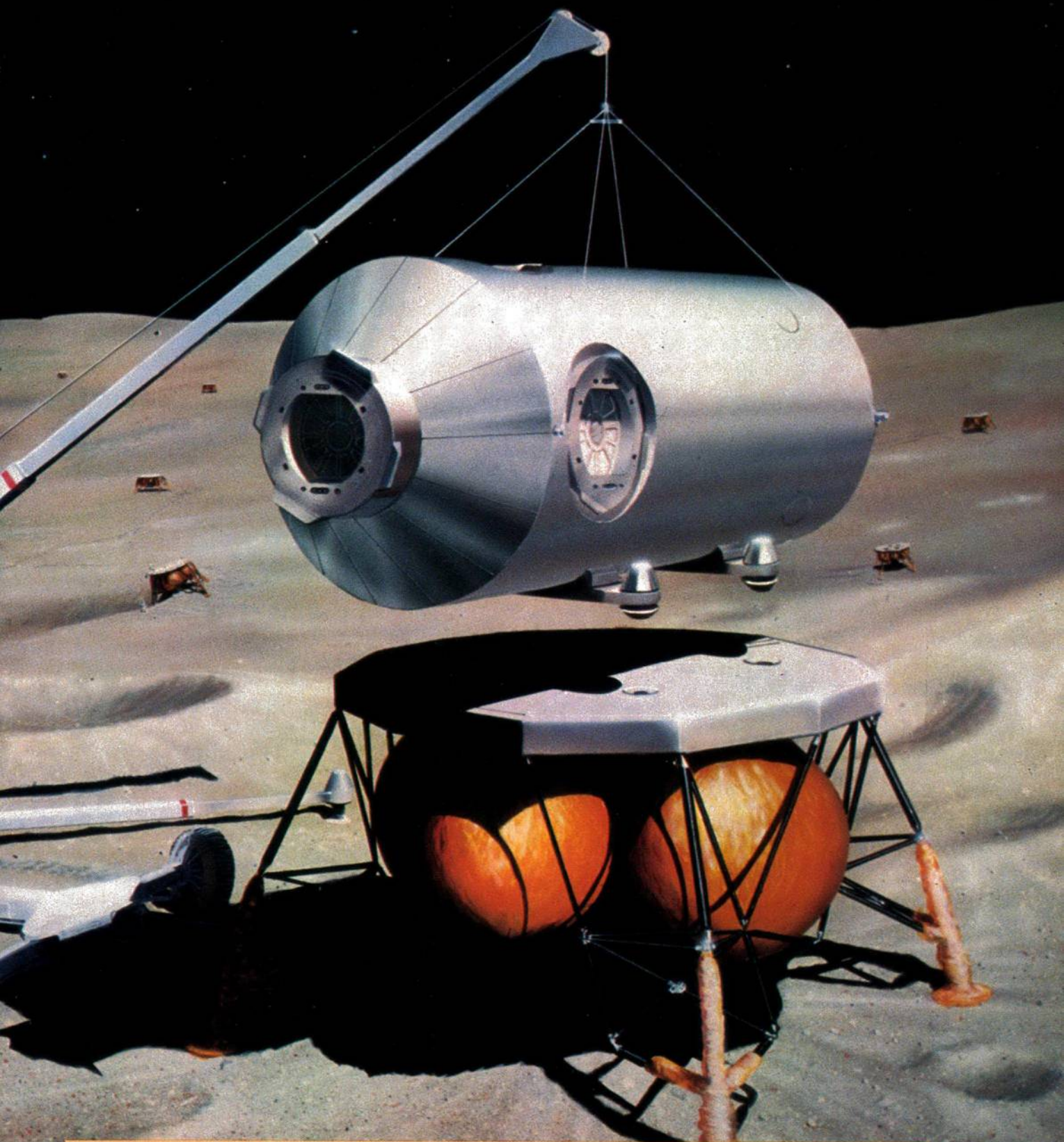
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20TH ANNIVERSARY OF APOLLO 11

From Footprints to Foothold

The next astronaut to set foot on
the Moon will not be a visitor but a long-term resident.
by Robert G. Nichols





A LABORATORY MODULE ferried from Earth reaches the Moon base. The base is the centerpiece of an ambitious plan to explore — and exploit — our satellite perhaps twenty years hence.

Pat Row



FACTORIES ON THE MOON, such as this solar-powered installation for extracting oxygen from the soil, will pioneer ways to open up the solar system to human habitation.

When Neil Armstrong stepped onto the lunar surface, the eyes of the world focused on the Moon. Twenty years later, Americans are once again looking toward the Moon as the next goal for our manned space effort. This time, however, there is no talk of quick visits to a few scattered locations. Today the discussion is of permanent bases, where perhaps two decades from now scientists can conduct long-term research and commercial enterprises can gain a profitable beginning.

The call for a renewed lunar program hasn't met with universal acclaim, however, even within the space community. Some argue that America should focus its energies on sending people to Mars. Still others argue that manned space exploration is a thing of the past. Advances in robotics and artificial intelligence, they say, make manned space exploration little more than expensive publicity stunts. They feel the money should be spent on exploring the solar system with unmanned craft.

To determine just what America's long-term future in space might be, NASA established the Office of Exploration in the summer of 1987. This office is creating case studies of possible space projects to find out what we need to know to carry them out. These "paper missions" are the first time the space agency has made a systematic study to chart the future U.S. space agenda. Case studies under consideration include manned missions to Mars and to asteroids that cross Earth's orbit, as well as several types of manned lunar missions.

A case study titled "Lunar Evolution" describes a program to put humans permanently on the Moon within twenty years. The first manned mission in 2004 would set up a base camp, probably covered with lunar soil to protect the occupants from solar radiation. The primary task facing the four-person crew will be to prepare the camp for continuous occupation by later crews.

In the Lunar Evolution scenario, supplies for the

lunar base are ferried from Earth to the Space Station in low-Earth orbit. From there the supplies go to the Moon in a reusable orbital transfer vehicle — a space tug or cargo ship. In the early days the cargo ship may descend directly to the lunar surface with supplies and rocket back to Earth orbit with returning crew members. Later, a space station will be placed in lunar orbit. The cargo ship will rendezvous with the lunar space station to transfer supplies to a lunar ferry traveling down to the surface.

Subsequent Moon base crews will try to make the base as self-sufficient as possible. Oxygen will be extracted from the lunar soil. Water will be produced by combining the extracted oxygen with hydrogen, also obtained from the soil. Lunar hydrogen and oxygen will provide a propellant for rockets traveling to and from the Moon's surface. Building materials — concrete, high-strength glass, and metals — can be manufactured from the lunar regolith.

NASA officials plan to present the case-study results to the president in the next few years, in the hope of finding funding for one of the projects.

A large portion of the science community and aerospace industry is interested in the possibilities of a return to the Moon. There is even growing support from terrestrial industries that aren't into aerospace, according to Michael Duke, chief of the solar system exploration division at NASA's Johnson Space Center. Duke said, "Representatives from major construction companies are now thinking about the role their companies would play in an era when we are constructing things on the Moon."

The idea of a lunar program that includes base camps evolving into self-sufficient communities strongly appeals to those with a long-range vision of humankind's migration into space. Because of its low gravity and abundant raw materials, the Moon could make an extensive space transportation system economically possible. Lunar metals can be used to make spacecraft, space stations, and even huge solar

power satellites to provide energy for Earth. Lunar hydrogen and oxygen could fuel the rockets plying cislunar space as well as interplanetary spacecraft. The Moon's low escape velocity will make it more economical (in energy terms) to launch the materials from the lunar surface than from Earth.

Returning to the Moon is something that offers benefits in three major areas: studies of the Moon itself, doing astronomy from the Moon's surface, and developing the Moon industrially.

Rationale #1: Lunar Science

Perhaps the most obvious scientific reason to go back to the Moon is to pick up where *Apollo* left off. After all, it's impossible to understand a planet from just six expeditions that lasted only a few days each. The 841 pounds of rock and soil samples returned by *Apollo* didn't begin to answer all our questions about the Moon. The samples, for instance, came from only six sites clustered on the nearside of the Moon.

Jeffrey Taylor is a planetologist who would like to see America establish manned research stations on the Moon. A professor at the University of New Mexico, Taylor said, "There's a school of thought promoted by a certain famous astronomer that says the Moon is a boring place." Taylor doesn't agree. He and other planetologists believe they have a lot still to learn from the Moon.

Questions that perplexed geologists even before *Apollo* can be answered only by additional lunar research. For example, data brought back by astronauts suggests that the Moon had a molten surface when it formed. Did this magma ocean exist and what does it indicate about the evolution of the Moon? How thick is the crust? What is its composition? Does the Moon have a molten iron-nickel core? What are the relationships between the major types of lunar rocks? For that matter, have scientists identified all the major types of lunar rocks?

It will take more than just a couple of quick surveys of scattered sites to answer these and other questions. A systematic and detailed study continuing for many years and covering the entire Moon, including the farside and the polar regions, is needed. Taylor says lunar scientists across the country have already identified sixty sites to be studied by astronaut/geologists. An unmanned lunar polar orbiter spacecraft will also target prospective locations.

Lunar research, Taylor explained, will be conducted in two phases: reconnaissance and field work. Reconnaissance involves sending automated landers to scoop up samples from dozens or hundreds of sites. This is a cost effective way to catalogue the lunar surface because landers will be relatively inexpensive. The information gathered by the landers will determine the best location for the first Moon base.

After the base is established, space-suited geologists will embark on field work. Besides collecting rock and soil samples, they will set up a variety of instruments and sensors to monitor lunar conditions. Taylor predicts that geologists riding in lunar rovers will range up to 50 miles from the base camp.

Beyond the 50-mile limit, scientists will employ sophisticated, remote-controlled rovers. Equipped with video cameras, scoops, and grappling claws, the rovers will spend months roaming far beyond what is

possible for human geologists. Samples will be returned to the base camp, and if a particularly exciting site is discovered, a crew will investigate.

Much of what scientists learn about the Moon will also provide information about the evolution of the other planets. For instance, because Earth is geologically active, the record of its earliest times has been erased. Taylor noted that on the Moon, the record of the earliest period (about 4.5 billion years ago) appears better preserved than anywhere else.

The Moon is also an excellent place to study cratering, which has shaped the surfaces of all terrestrial planets. "All but the most recent craters on Earth have been eroded by geological and environmental processes," Taylor said. "Even the craters on Mars are badly eroded and degraded. The Moon, however, has old craters hundreds of kilometers across just waiting to be studied in detail."

Rationale #2: Lunar Astronomy

The second reason to return to the Moon is to use it as a platform from which to survey the universe. A manned lunar base opens a new era for astronomy, according to Harlan Smith, director of McDonald Observatory. An outspoken advocate of lunar astronomy, Smith claims that "most kinds of astronomy can be done better on the Moon than anywhere else."

What makes the Moon so appealing to astronomers is the lunar environment — or lack of it! First, the Moon has no significant atmosphere. (A good size theater holds as much gas as the entire lunar atmosphere.) This means telescopes on the Moon avoid atmospheric turbulence and clouds.

Also, the lunar sky is four times darker than the best Earth sky, making the Moon an excellent place for deep-space observations. Even during the lunar day, the sky is dark enough for all but ultra-deep observations. In addition, lunar nights are two weeks long, which makes extremely long exposures of faint objects possible.

A dark sky free of atmosphere isn't unique to the Moon, however. It's also one of the reasons for putting observatories in orbit around Earth. But the Moon has an important feature not found in orbit: stability. The *Hubble Space Telescope* is costly in part because of the sophisticated equipment needed to precisely aim at celestial objects when the craft can swing freely in any direction. In contrast, a lunar-based telescope can easily track stellar objects using the solid planetary surface to work against.

Radio astronomers will take advantage of the lunar farside, which is constantly shielded from Earth's radio noise. "On the farside, the premier facility will be a very low-frequency radio astronomy array which will be operated between 0.5 and 30 megahertz," predicted Jack Burns, director of the Institute of Astrophysics at the University of New Mexico. "That band is inaccessible from Earth and even Earth-orbit because of the high background noise. The farside of the Moon is the *only* location in the inner solar system that can open up this window, which astronomers have yet to peer through," Burns said. Farside observatories won't be built until years after the first lunar base, but their benefits are so great that they are a certainty someday.

Lunar astronomy could begin with the first lunar

base mission. Harlan Smith would like to see a small telescope carried up with the first mission to go back to the Moon. It will probably be a 1-meter telescope, which is big enough to do real research. Thereafter, each payload could include another small observatory or parts of a larger one.

The presence of all these observatories doesn't mean that the first lunar base crews must include astronomers. "Virtually all the lunar astronomy will be done from Earth," declared Smith. "The astronomers will remain in their offices on Earth and control the telescopes on the Moon by radio." The Moon is close enough that data can be transmitted back to Earth in real time.

There is some concern that human activity on the Moon will interfere with astronomical observations. When the lunar soil is mined for oxygen and hydrogen, gases will be released. These gases are so loosely bound to the soil that any human activity on the surface is likely to release them. In addition, constantly launching rockets may increase the atmosphere locally. If out-gassing occurs significantly, an appreciable local atmosphere could be generated.

Astronomers and lunar scientists haven't decided yet if the build-up of a manmade atmosphere will actually be a problem or not. "A couple of studies have been done," said Michael Duke, "but the final answers are not in yet." Many think it will probably take years of intensive human activity before the atmosphere increases enough to affect lunar astronomy, and others have concluded that problem can be avoided by placing the telescopes 10 to 150 kilometers away from the base camp or mining operations.

Despite these concerns, many astronomers believe that much of the next century's path-breaking astronomy will be done from the lunar surface. For example, Jack Burns noted that because the Moon has no atmosphere to speak of and is seismically stable, it is perfect for long baseline optical interferometry. About 10 kilometers across and consisting of thirty to fifty 1-meter optical telescopes electronically linked, the lunar interferometer could obtain an imaging resolution on the order of 10 microarc-seconds. "That's a full five orders of magnitude better than what we can do from the surface of the Earth," said Burns. "It's even a factor of 10,000 better than what we can do with the *Space Telescope*!"

The great increase in resolution opens up vast new areas for astronomy, explained Burns. With a lunar interferometer, he said, "You can search directly for planets around stars. You might even be able to image an Earth-like planet orbiting the nearby star Tau Ceti." It might also be possible to produce images of active regions on other stars, called "star spots."

All this is not to say that lunar astronomy will mean an end to Earth-based astronomical research. Though Harlan Smith expects "the lion's share of frontier astronomy could be done from the Moon as early as 2015," he thinks there will be plenty of work for observatories on Earth. Smith envisions that his own McDonald Observatory "will be humming along in those dim, distant days because of the advantages of immediate access for training, instrument testing, and spectroscopy."

Jack Burns admits that it has been a bit of a struggle to make astronomers see the advantages of placing equipment on the Moon. This really doesn't surprise Burns, who says many astronomers were skeptical of the *Space Telescope* when it was first proposed in the early 1970s. Today, of course, astronomers are solidly behind the orbiting observatory. Burns hopes most astronomers will eventually be sold on lunar-based astronomy.

"One of my goals over the past few years," said Burns, "has been to build a case for the astronomical science that can be done from the Moon." To accomplish this, he has helped organize and run three workshops on lunar astronomy open to the astronomy, space science, and engineering communities. So far the results have been encouraging, Burns notes. Participants leave the workshops excited about the development of lunar astronomy programs.

Rationale #3: Lunar Industry

The long-term success of a lunar base will depend in large part on establishing facilities to extract oxygen, hydrogen, and metals from the lunar soil and to produce water, air, fuel, and construction materials. The Lunar Evolution case study, for example, has the Moon base producing fuel during the first crew's six-month tour of duty.

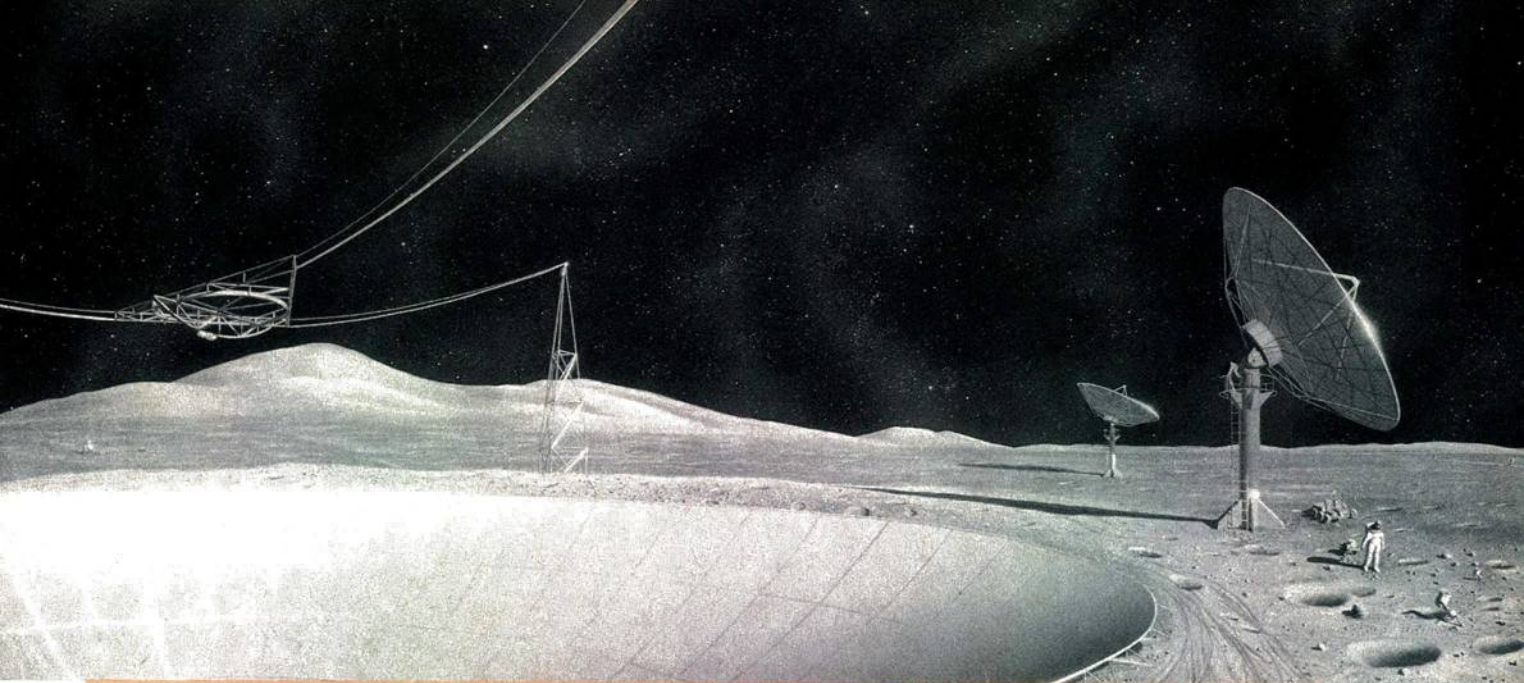
Initial lunar processing and manufacturing plants will be operated by the government. Eventually, however, private industry could take over. Governments have often proven woefully inadequate in developing resources and running businesses. The commercial development of lunar resources is one of the important issues being examined by NASA's Office of Exploration.

One organization focusing on lunar industry is the Space Studies Institute. A space research organization located in Princeton, New Jersey, the Space Studies Institute promotes the economic development of space and lunar resources. Gregg Maryniak, executive vice president, said, "We envision lunar bases to be more like North Sea oil rigs and less like the research bases at Little America in the Antarctic." This doesn't dismiss lunar science bases as unnecessary. The Institute has concluded that developing lunar resources will make it easier to explore the Moon and solar system and will provide concrete benefits to people on Earth. Industrial Moon bases, Maryniak says, could even lease space to NASA for research.

Before private companies can profit by the Moon, there has to be a market for the lunar products, which won't be found on Earth. There's nothing the Moon can produce that can't be produced cheaper on Earth. So the market for lunar products will be in space.

As manned space activity increases, there will be a growing need for fuel, water, and air, all of which can be produced on the Moon by extracting and refining lunar hydrogen and oxygen. This will be the market that lunar industries will target.

The reason for using the Moon for space supplies is that it takes less energy to ship material from the Moon to low-Earth orbit than to ship the same material up from Earth to orbit. It may be as much as 20 to 50 times cheaper to launch a payload from the Moon rather than Earth, according to Wendell Men-



A RADIO OBSERVATORY on the lunar farside will shield ultra-sensitive instruments from Earth's radio noise with a screen of rock — the Moon itself — thus allowing the telescope to see deeper into space.

dell, chief scientist for lunar base studies at NASA's Johnson Space Center. As Mendell pointed out, "A space shuttle devotes about 1.5 percent of its liftoff mass to payload. On the Moon, a spaceship going to Earth orbit can devote about 50 percent of its mass to payload."

To further reduce the shipping costs, a unique launch system called a mass driver may eventually be built on the Moon. This is a key element in the Space Studies Institute's lunar industrialization scenarios. Several miles long, a mass driver uses magnetic pulses to accelerate a cargo container up to lunar escape velocity and hurls it directly into space.

Because the container experiences several hundred Gs of acceleration, the mass driver is unsuitable for humans but ideal for raw materials. Ores could be mined and the metals (iron and titanium) could be refined on the lunar surface. They could then be shipped to low-Earth orbit to be worked into useful structures and components. Even plain lunar soil could be shipped into space to be used as radiation shielding for crew areas in space habitats.

This ambitious and admittedly optimistic vision of lunar commerce won't be realized until well into the twenty-first century. Not only will a lunar base have to be established but also a robust space transportation system so lunar industries will have a market. However, the seeds of such enterprises will be sown when the first lunar base hands over oxygen and hydrogen processing to a private company.

Beyond Moon Bases

An important function of a manned lunar base right from the start will be to support manned exploration of the solar system. Not only will lunar bases supply voyages to other planets, but they will also help NASA learn how to keep people healthy in a totally closed environment.

At first glance, the Space Station might seem the best place for such research. However, the Station won't be designed as a closed environment. While

there will be efforts to recycle air and water, on the whole the Station will be an open-ended system because it will need periodic shipments of consumables. At a Moon base, however, astronaut crews will begin growing food as well as recycling air, water, and waste material.

Also, physiologists have found that prolonged zero-gravity, unavoidable when traveling to and from Mars, has a number of debilitating effects on people. Besides the loss of bone calcium in zero-G, the cardiovascular system becomes deconditioned. Lunar research can tell if a reduced gravity environment alleviates or eliminates these effects.

Once a Moon base and lunar industry are going concerns, interplanetary voyages will suddenly become economically feasible. The metals and glasses of interplanetary spacecraft will have been mined from the Moon. Oxygen and hydrogen to fuel the engines will be lunar-extracted. Even the food for the journey could be grown on lunar farms and hydroponic facilities. In addition, lessons learned by establishing the manned lunar bases will enhance the success of missions to distant planets.

The near- and long-term benefits of a Moon base are obvious, but some still advocate a manned Mars mission as our next big step. Yet such an effort would be reminiscent of the *Apollo* program, because the program wouldn't lead anywhere. There is no logical next step after a Mars mission. In contrast, a Moon base program, properly conceived and implemented, will lead to the development of lunar and space resources and to increased spaceflight capabilities.

As Gregg Maryniak put it, "When you go to Mars, all you have is Mars. When you go to the Moon, you open up the entire solar system." □

Robert G. Nichols is a free-lance writer specializing in science and technology who lives in Massachusetts.

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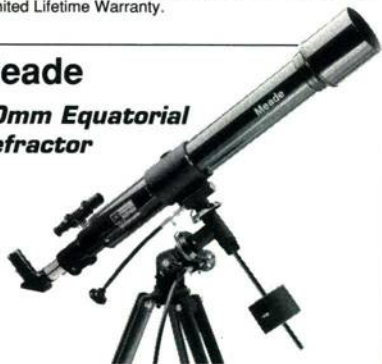


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North

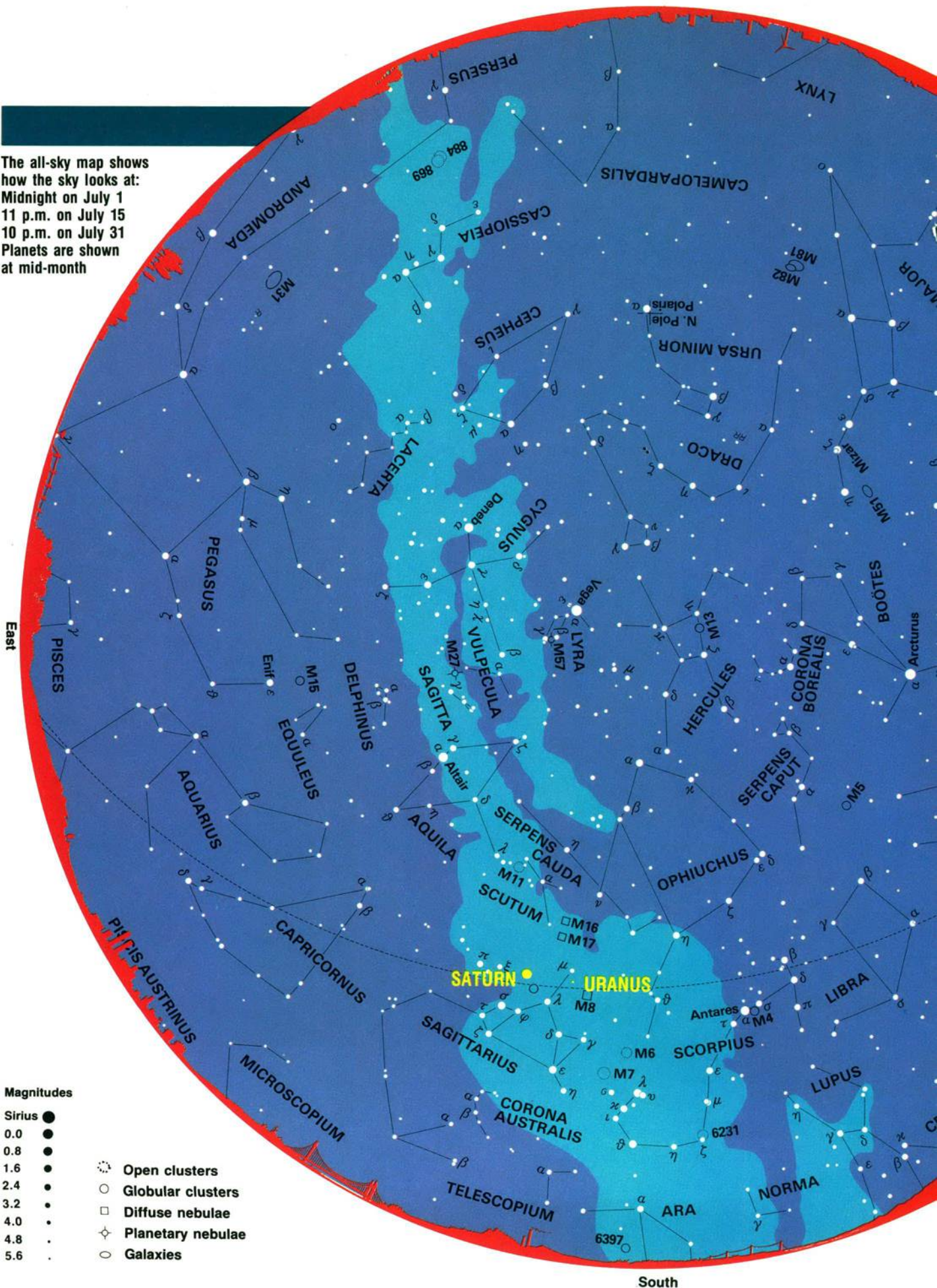
The all-sky map shows
how the sky looks at:
Midnight on July 1
11 p.m. on July 15
10 p.m. on July 31
Planets are shown
at mid-month

East

Magnitudes

Sirius ●
0.0 ●
0.8 ●
1.6 ●
2.4 ●
3.2 ●
4.0 ●
4.8 ●
5.6 ●

- Open clusters
○ Globular clusters
□ Diffuse nebulae
✧ Planetary nebulae
○ Galaxies



Sky Almanac

JULY 1989

STARLIGHT PIERCES SATURN'S RINGS

Saturn passes in front of the 5.8-magnitude star 28 Sagittarii on the night of July 2/3. As the star's light filters through the material in Saturn's ring system, telescope owners get a rare opportunity to observe some of the rings' complex structure.

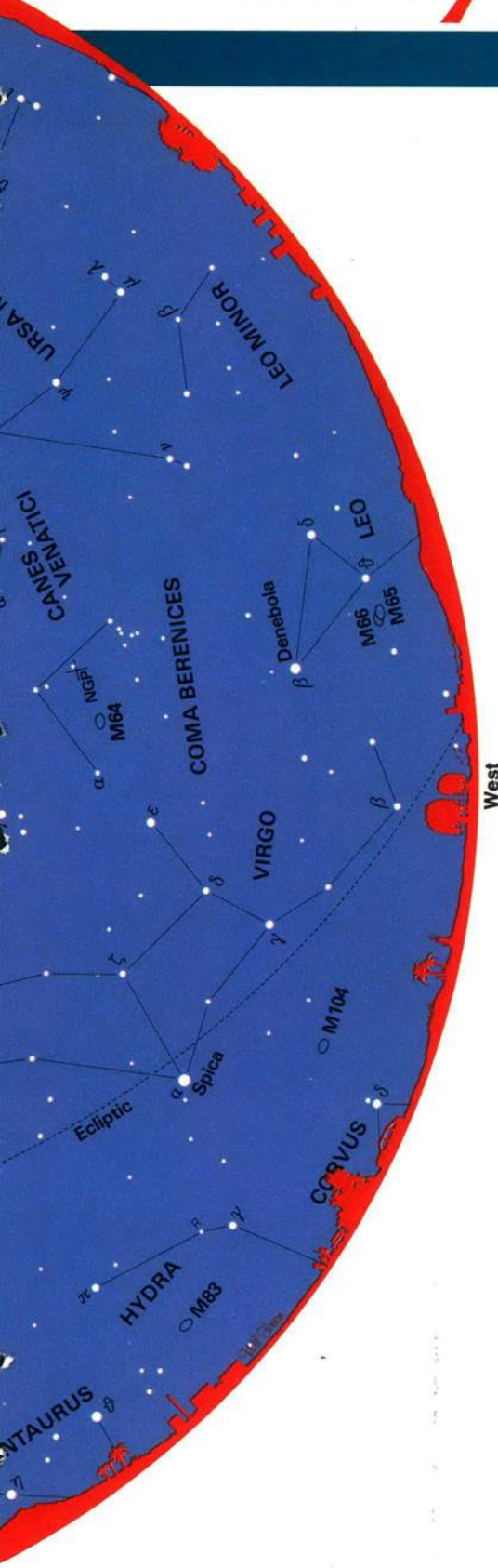
TWO PLANETARY CONJUNCTIONS

Two pairs of planets pass each other this month. Mercury and Jupiter lie less than a degree apart on the morning of July 2. Venus and Mars edge within half a degree of each other on the night of July 13.

THE MOON BLOCKS THE PLEIADES

A slim crescent Moon passes in front of the Pleiades on the morning of July 27. Use binoculars or a low-power telescope to see the event from the western United States and western Canada.

Dates and Times

- 
- 1 The Moon passes 5° north of Jupiter, 7 p.m. EDT
 - 2 Saturn is at opposition
Mercury passes 0.6° south of Jupiter, 1 p.m. EDT
Neptune is at opposition
 - 3 New Moon is at 12:59 a.m. EDT
Saturn occults 28 Sagittarii
 - 4 Earth is at aphelion (94.5 million miles from the Sun)
 - 5 The Moon passes 0.1° north of Venus, midnight EDT
The Moon passes 0.09° north of Mars, 8 a.m. EDT
 - 6 The Moon passes 0.9° south of Regulus, 7 p.m. EDT
 - 10 The Moon is at apogee (251,128 miles from Earth), 4:51 p.m. EDT
First Quarter Moon is at 8:19 p.m. EDT
 - 12 Venus passes 0.5° north of Mars, 8 a.m. EDT
 - 15 The Moon passes 0.5° south of Antares, 1 a.m. EDT
 - 17 The Moon passes 4° south of Saturn, 8 a.m. EDT
 - 18 Mercury is in superior conjunction
Full Moon is at 1:42 p.m. EDT
 - 21 Mars is at aphelion
 - 23 The Moon is at perigee (228,932 miles from Earth), 2:59 a.m. EDT
Venus passes 1.2° north of Regulus, 7 a.m. EDT
 - 25 Last Quarter Moon is at 9:31 a.m. EDT
 - 27 The Pleiades are occulted by the Moon
 - 28 Pluto is stationary
Delta Aquarid meteor shower is at its peak
 - 29 The Moon passes 5° north of Jupiter, noon EDT

SATURN AT ITS BRIGHTEST

In early July Saturn shines at magnitude 0.0, its brightest for 1989. On the night of July 2, Saturn appears opposite the Sun in our sky, a configuration called opposition. On this night the planet rises in the east-southeast at sunset, wheels across the sky throughout the night, and disappears below the west-southwestern horizon when the Sun comes up at dawn. It appears as a steady light in the constellation Sagittarius, the most star-cluttered region of the sky.

Saturn appears brightest to us because it is now at its closest to Earth for the year. In its large orbit around the Sun, Saturn has now pulled within about 840 million miles of Earth.

By the end of July, Saturn begins to fade as Earth rushes ahead in its smaller orbit and the distance between our world and Saturn increases. Make sure to watch for Saturn this month, gleaming and golden, the farthest planet in our solar system that is easily visible to the naked eye.

TWO PLANETS: COMPANIONS IN THE SKY

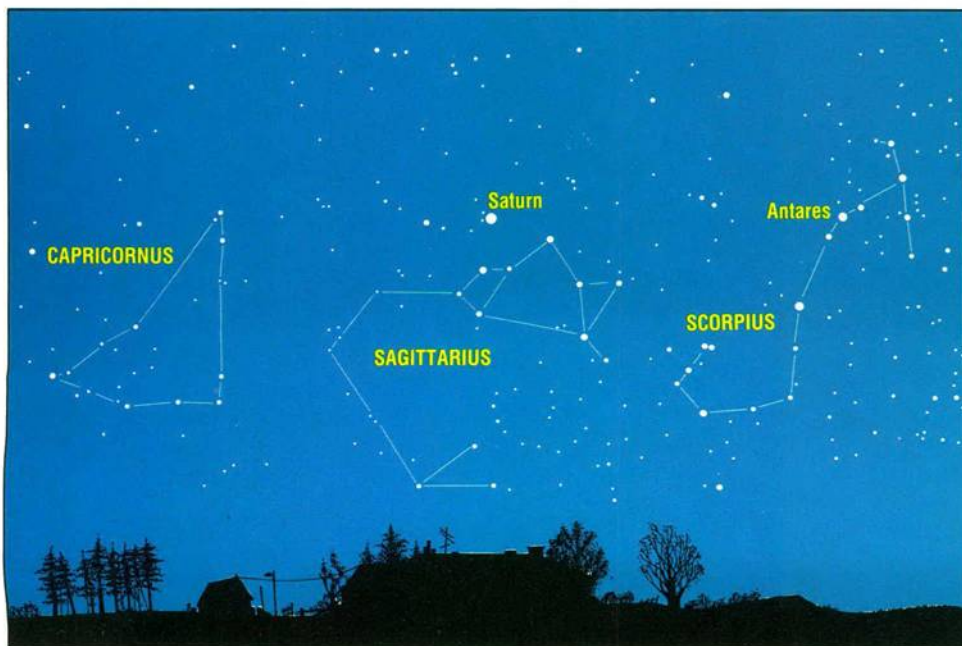
Venus and Mars play out a drama this month that they began a little over a month ago. Around the end of May, Venus came into view low in the evening twilight sky. This month the brightest planet continues to pull slowly away from our line of sight to the Sun. Meanwhile, Mars continues to sink closer to the Sun's line of sight.

The two planets appear to creep toward one another until July 12, when they lie just 0.5° apart. Venus is unmistakably the brighter of the two. The -3.9 -magnitude planet is nearly 200 times brighter than Mars, which shines at magnitude 1.8.

These two worlds can never appear near each other in our sky when Mars is bright. Venus is always brilliant, but Mars is very bright only around the time of opposition. Because Venus is an inner planet, it always appears near the Sun. For these two worlds to meet, Mars must lie in the direction of the Sun as well, which means that it must be far from opposition. Thus, Mars is destined to look faint whenever it appears near Venus.

A slim, waxing crescent Moon joins Venus and Mars early this month. The Moon is New, or nearest to a direct line between Earth and the Sun, the night of July 2/3. You'll probably see it in the evening sky first on July 4, when it is closest to Venus. A slightly fatter crescent Moon appears a few degrees above Mars the next evening.

SATURN SHINES BRIGHTLY this month as it reaches opposition in Sagittarius. Look for the planet in the south around midnight.



METEOR SEASON BEGINS

Late summer marks the start of one of the better times of year to watch meteors. The long, rambling Delta Aquarid shower, with meteors appearing to radiate from a point in eastern Aquarius, extends from mid-July to the end of August. This shower produces more total meteors than any other shower of the year, but because the shower stretches over such a long time and does not have a sharp peak, it doesn't produce a lot of meteors on any one night. That is why the Delta Aquarids are not as famous as next month's Perseid meteor shower.

By the end of July, the first Perseids also come into view, streaking through clear, dark skies. This year the Perseids build grad-

ually until they peak on the morning of August 12. The combined strength of the Perseids and Delta Aquarids make the hours after midnight during late July and early August a good time to search for meteors. (This year the Moon is New on August 1, so it won't interfere with meteor observing.) As usual, the key to seeing lots of meteors is to avoid city lights and observe when the Moon is out of the sky.

JULY'S PLANETS

Venus can be found low in the west-northwest after sunset this month. It is brilliant — the brightest object in the sky except for the Sun and Moon — but destined to remain low in the sky all summer. By autumn it will edge a bit higher in the sky, but not much.

Venus now lies close to Mars, the Red Planet. The two are closest on July 12, when they pass 0.5° from each other, but the movements of the two planets and the sharp contrast in their brightnesses make them fun to watch all month. In the coming months, Venus in its smaller, faster orbit will be catching up to Earth. Mars, on the other hand, is now hopelessly behind Earth in its larger, slower orbit and will soon be behind the Sun from our vantage point.

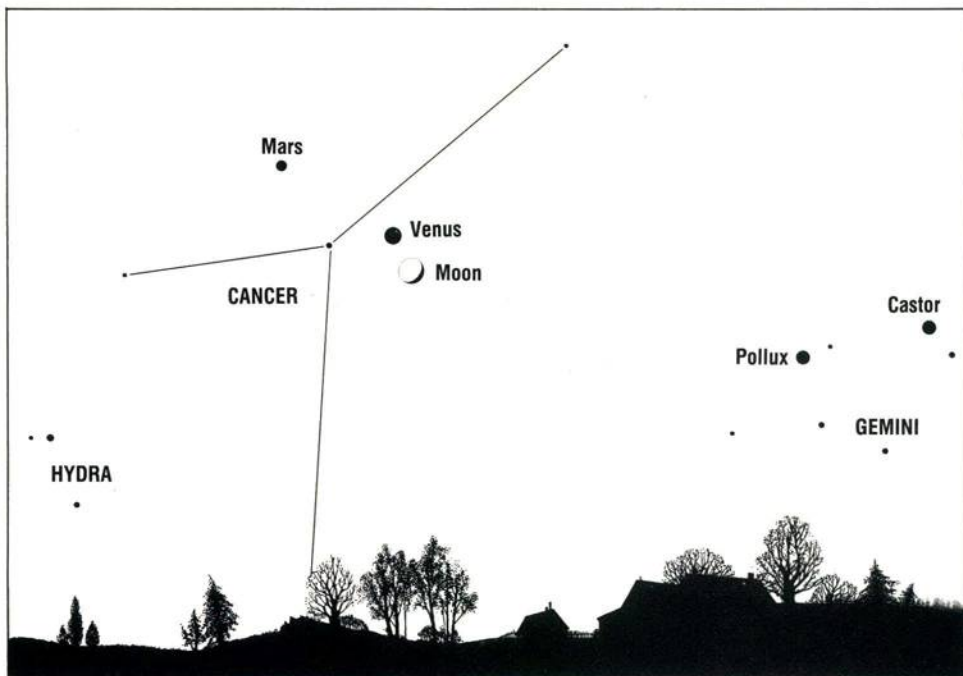
Venus and Mars also lie near a bright star, Regulus, the heart of the lion in the constellation Leo. Regulus appears closest to Venus on July 23 and closest to Mars on August 2, when the star and planet will be low and very hard to see. Both Mars and Regulus are sinking rapidly toward the Sun and will be lost in the Sun's glare by mid-August.

Saturn shines at opposition on July 2, a bright, steady light against the background of Sagittarius, and is visible all night long. As the constellations slip westward during the night, Saturn traces a low arc across the southern sky for Northern Hemisphere observers. All the planets travel more or less along the ecliptic (the Sun's apparent path across the sky), but the part of the ecliptic Saturn now lies in rides low in the sky.

Two other planets lie in Saturn's vicinity, but they are nowhere near as bright. Although Uranus is visible to the naked eye, it is hard to locate among the many stars of Sagittarius. If you are observing under a dark sky, try holding your fist straight out toward Saturn when that planet appears in the south. You should spot Uranus about one fist's width to Saturn's right. Neptune, which can be seen in binoculars but is invisible without optical aid, lies much closer to Saturn and is visible just above the bright planet. As you gaze at this region of the sky, remember that the *Voyager 2* spacecraft is now streaking toward its rendezvous with Neptune. Next month we will get our first close-up view of what is now the solar system's outermost planet.

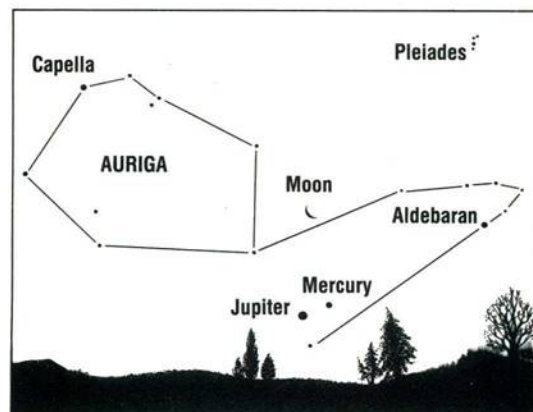
Mercury is barely visible before dawn at the start of July, and you will probably have to search for it. That's too bad, because on July 2 Mercury is less than 1° from Jupiter, which is now returning to view after being behind the Sun.

Your best chance to see the close pair is on the morning before July 2. On July 1 a slim crescent Moon lies about 8° above Mercury and Jupiter along the east-northeastern horizon and may help you locate the planets. Mercury shines brightly at magnitude -0.6 , and Jupiter is even brighter at magnitude -1.9 . Still, you may need binoculars to find the pair because of their low elevation and the bright twilight glow.



MARS AND VENUS lie near each other all month and join with the Moon to form an attractive grouping on the evening of July 4. Catch the trio low in the west-northwest about thirty minutes after sunset.

JUPITER AND MERCURY pass within 1° of each other on July 2, but you may get a better view of the close pair on July 1, when they lie 8° below the slender crescent Moon 30 minutes before sunrise.



Our own planet reaches aphelion, its farthest point from the Sun, on July 4. It lies 94.5 million miles from the Sun and moves at its slowest orbital speed, about 18 miles per second.

JULY'S STARRY SKY

As you gaze toward Saturn and the Moon on the night of July 16/17, you are looking in the approximate direction of the center of our Milky Way Galaxy.

Saturn is now in the constellation Sagittarius. Sagittarius represents an Archer in mythology, but modern observers often see it as a teapot. The Teapot of Sagittarius is distinctive and easy to see. A 3rd-magnitude star, Kaus Borealis or Lambda (λ) Sagittarii, marks the top of its lid. A star of similar brightness, Gamma (γ) Sagittarii, shines at the tip of its spout. The direction to the center of the Milky Way lies 5° west of the spout.

On a clear night, free of moonlight and artificial lights, look in this direction. You will see a vast crowd of stars, so many that their light combines into a broad, milky-looking region, like a shimmering cloud.

It's easy to see the Milky Way as steam rising from the Teapot. There is also a second asterism, or grouping of stars, that can be imagined here. The handle and top of the lid of the Teapot, along with the star Mu (μ) Sagittarii, are sometimes called the Milk Dipper.

Although the stars in Sagittarius are located toward the center of the Galaxy, they do not lie in the exact center. Instead, the center of the Galaxy is hidden from our view by obscuring clouds of interstellar dust and the densely packed foreground stars.

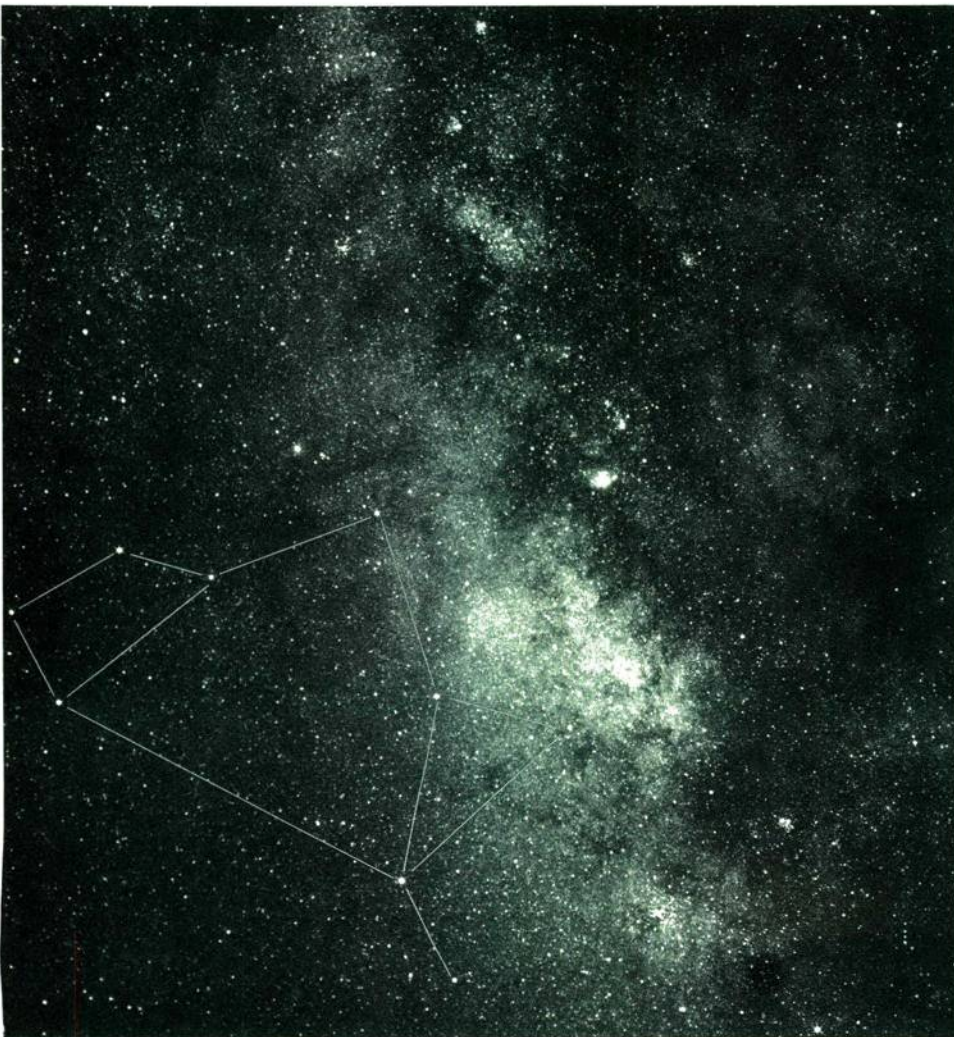
When we stand outside on a clear, dark night and look in this direction, we are looking at the spiral arm next inward from ours, called the Sagittarius Arm.

From Sagittarius in the southern sky, the band of the Milky Way runs upward through Scutum, Aquila, Sagitta, and Cygnus. It appears as a starry ribbon of hazy light, dotted with bright knots (star clusters) and streaked with mysterious dark areas, vast clouds of interstellar material from which new stars may someday be born. When we look at this band of stars, we are looking edgewise into the plane of the Galaxy.

The band looks hazy, but the haze represents the combined light of myriad distant stars. It's easy to turn the haze into something more distinct: Simply point your binoculars in its direction and some of the haze will resolve into stars.

Binoculars also help you discover that no other region of the sky is so rich as Sagittarius in easy-pickings for stargazers. There are a multitude of open star clusters in the disk of the Galaxy, and both bright and dark nebulae abound. You can easily lose track of the hours, reclined in a lawn chair, sweeping the Milky Way with binoculars. □

THE GREAT STARCLOUDS of Sagittarius are prominent in July from a dark site. Located near the constellation's Teapot asterism, this is the Milky Way's most spectacular expanse. Photo by M. R. O'Neal.



A RARE OCCULTATION BY SATURN

Saturn reaches opposition during the daylight hours of July 2, but Saturn's biggest event of 1989 occurs that night and the following morning when the ringed planet occults 28 Sagittarii. (See "You Can See a Star Flicker behind Saturn's Rings" by Jeff Kanipe, June 1989.) At magnitude 5.8, 28 Sagittarii is the brightest star occulted by Saturn until at least the twenty-second century. And to top things off, the occultation is visible from virtually everywhere in the Western Hemisphere.

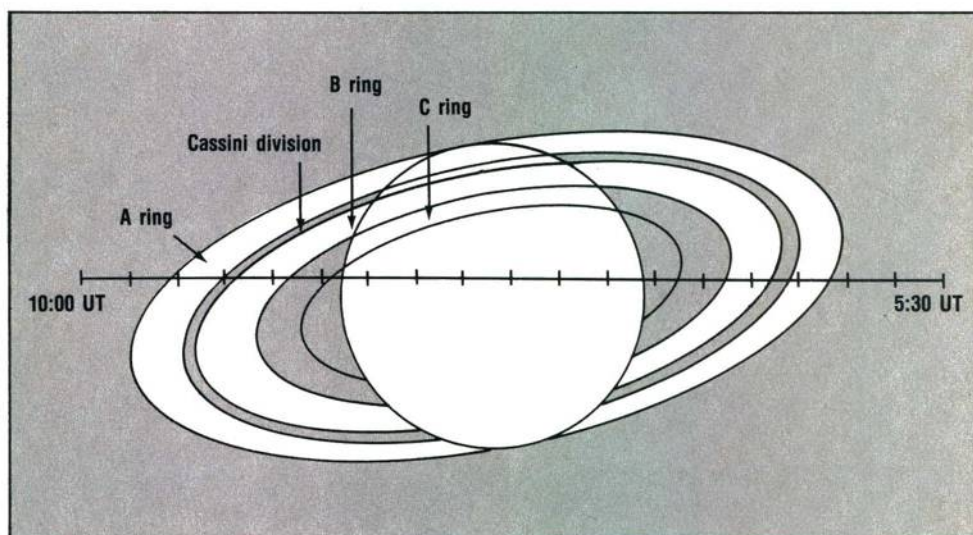
The rare event begins at approximately 6:00 universal time (UT) on July 3 (2:00 a.m. EDT, 1:00 a.m. CDT, midnight MDT, and 11:00 p.m. PDT on July 2), when the western edge of Saturn's rings first touches the star. The globe of Saturn passes in front of the star at approximately 6:50 UT, and the star is closest to Saturn's center at 7:40 UT. At that time the apparent center of Saturn lies only 1.8" from 28 Sagittarii. The star emerges from behind Saturn's globe at approximately 8:30 UT, and the occultation ends at around 9:30 UT when the eastern edge of the rings moves away from 28 Sagittarii. In all, the event lasts about three-and-a-half hours, so be ready to spend a lot of time at the eyepiece.

The most exciting aspect of the event is watching the star's light fade as it passes through dense regions of ring material and then brighten when it encounters gaps in the rings. NASA scientists used this same technique to probe Saturn's rings when the *Voyager* spacecraft flew by the planet in 1980 and 1981. At Saturn's distance from Earth, a single object roughly 10 kilometers in diameter would block all the light from 28 Sagittarii and an object one-tenth that diameter would block 1 percent of the star's light. Of course, the star's light is also diminished when it passes through swarms of smaller particles in Saturn's rings. Thus, the occultation provides a unique opportunity for backyard observers to see some of the complex structure in Saturn's ring system.

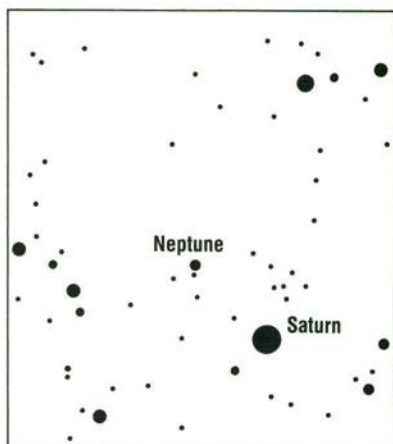
Capturing 28 Sagittarii on film or videotape as it peeks through the rings is another exciting possibility. The ratio of the brightness of the 0.0-magnitude planet to the 5.8-magnitude star is 210, which at first glance seems overwhelming. However, Saturn is also much larger. Saturn and its rings cover an apparent area of roughly 500 square arcseconds. If we assume that seeing smears the light from 28 Sagittarii over an area of 4 square arcseconds, then the ratio of Saturn's area to the star's area is 125. Thus, the star's apparent surface brightness is approximately 60 percent of Saturn's average surface brightness as seen from Earth. Both film and videotape can easily handle that small a difference in brightness. If the seeing happens to be better than that, the star's image is concentrated into a smaller area and appears even brighter.

Whether you photograph the event or observe it visually, you will get a better view if the seeing is good. Even though the event occurs near local midnight for much of the United States and Canada, Saturn has a southerly declination and therefore appears low in the sky where seeing is typically poor, which means your choice of an observing site is particularly important. Grassy meadows, parks, and sites near the ocean are all likely to have less atmospheric turbulence and better seeing than areas with obvious heat sources, such as buildings and parking lots.

But whatever site you choose, even if it's your backyard, make sure that your scope is set up and that you're ready well ahead of time. Even



AS SATURN PASSES IN FRONT of 28 Sagittarii on July 2/3, observers with a telescope can see the star's light flicker as it passes through the rings. Tick marks represent 15-minute intervals beginning at 5:30 UT on July 3.



LOCATE NEPTUNE at opposition by searching just northeast of Saturn. Even under good conditions, however, all you will see is the planet's 8th-magnitude gray-green disk. Photo by Geoff Chester and Richard Schmidt.



if this is the only observing you do on July 2/3, you won't be disappointed.

NEPTUNE AT OPPOSITION

Neptune reaches opposition on July 2, just ten hours after Saturn is at opposition. Although these two planets are separating slowly following their conjunction last month, Neptune begins July just 0.5° northeast of the ringed planet. Use the finder chart at far left to locate this planet.

Neptune appears bigger and brighter at opposition than at any

other time of the year. Still, the planet only shines at magnitude 7.9 and sports a bluish gray disk just $2.3''$ in diameter. Opposition is also the best time to search for Neptune's largest moon, Triton. The 13.5-magnitude point of light orbits Neptune at a distance ranging from $8''$ to $17''$ and can be glimpsed in an 8-inch or larger telescope under good conditions. (See "Observe the Moons of the Outer Planets" by Richard L. Talcott, June 1989, for more details on finding Triton and the moons of Saturn and Uranus during July.)

A PLEIADES OCCULTATION

Observers in much of the western United States and western Canada can see the Moon pass in front of the Pleiades before dawn on July 27. The slender crescent Moon, two days past Last Quarter phase, appears 29-percent lit.

The waning Moon traverses the northwestern part of the Pleiades. There it blocks the light from two 4th-magnitude stars, 19 Tauri (Taygeta) and 20 Tauri (Maia), and the 6th-magnitude star 18 Tauri. Unfortunately, the disappearances of the stars, which occur along the Moon's bright limb, cannot be seen, so you'll have to watch for the stars to reappear along the Moon's dark limb. Observers in eastern North America won't see any of these occultations, but they can see the Moon poised just west of the cluster in the hours before dawn.

To observe this event — the last good Pleiades occultation visible from North America this year — you'll want to use sturdily mounted binoculars or a low-power telescope. Be ready well ahead of time, particularly if you want to take a series of photos showing the Moon's motion through the cluster. The three bright stars all reappear from behind the Moon between approximately 3:30 a.m. and 4:00 a.m. PDT (4:30 a.m. and 5:00 a.m. MDT) (the earlier times occur in the southwest part of the viewing area).

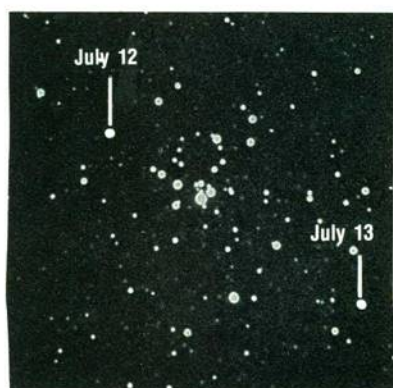
TELESCOPIC PLANETS

Two interesting planetary conjunctions occur in July. Early on the morning of July 2, Mercury passes just 0.6° south of Jupiter in the morning twilight. The two planets are only 17° west of the Sun, however, so you have to pick an observing site with a very low horizon toward the east-northeast. Observing from the shore of a lake or the ocean is ideal, as long as no mist or fog obscures the horizon.

Begin observing about forty minutes before sunrise, or about 4:50 local daylight time. If you have a well-aligned equatorial telescope equipped with setting circles, you can find the planets by "dialing-in" the coordinates of Jupiter. (Jupiter's position is right ascension 5h33.7m, declination $22^\circ 56'$.) If you don't have setting circles, use binoculars or your finder scope to locate the planets by sweeping the horizon between azimuth 55° and 75° .

This conjunction is unusual in that Mercury and Jupiter have similar

VESTA TRAVERSES M21, a 6th-magnitude open cluster in Sagittarius, on July 11/12 and 12/13. Positions are for 6 UT on the date listed (2 a.m. EDT, 1 a.m. CDT, midnight MDT, and 11 p.m. PDT the night before). Photo by Martin Germano.



brightnesses. Mercury's total magnitude is -0.6 , while that of Jupiter is -1.9 . Even though Jupiter is more than a magnitude brighter than Mercury, its surface brightness is lower because Jupiter's light is spread over a $32.5''$ disk, while Mercury's light comes from a gibbous disk $6''$ in diameter.

As you observe the two planets, look for the contrast between Mercury's yellow-white disk and the cream and brown colors of Jupiter's zones and belts. As July progresses, Mercury sinks into the Sun's glare and is lost from view. Jupiter, however, is rising out of the horizon murk and becomes better placed in mid- and late July.

The second planetary conjunction this month offers a close approach of Venus and Mars on the evenings of July 12 and 13. Venus makes its closest approach to Mars, passing just 0.45° north of the Red Planet, during the daylight hours of July 13. However, the two planets lie less than 1° apart low in the west-northwest just after sunset on both the 12th and 13th.

The contrast between Venus and Mars is much more pronounced than it was between Mercury and Jupiter. Venus' bright white disk measures $11.2''$ in diameter, while Mars' dim ocher disk is just $3.7''$ across. There is a 5.7-magnitude difference between -3.9 -magnitude Venus and 1.8-magnitude Mars, although the surface brightness of Venus is only 3.5 magnitudes brighter than that of Mars because the light is spread out over a larger area.

Saturn's occultation of 28 Sagittarii is the best event in an excellent month for Saturn. The ringed planet is at opposition on July 2, when it shines brightly at magnitude 0.0. On that date the planet measures $18.3''$ across its equator and its rings span $42.1''$.

Although the details in Saturn's cloud tops never become as obvious as those of Jupiter's, they are still worth pursuing. If the seeing is good, look for one or more equatorial belts and try to determine whether Saturn's polar region is darker than the rest of the disk.

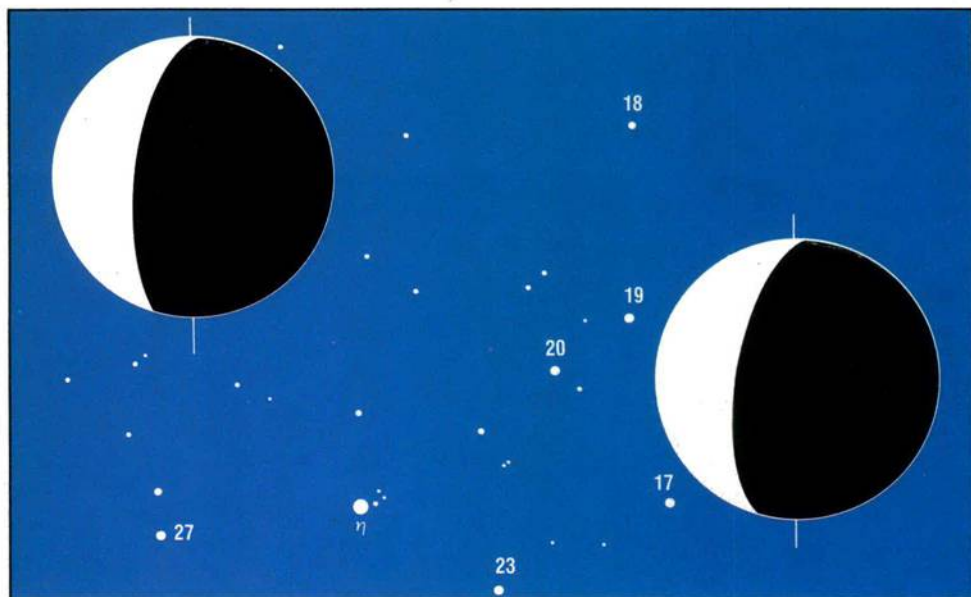
Uranus reached opposition just a week before the beginning of July, so it remains relatively large and bright throughout this month. Look for Uranus in Sagittarius about 8° west and 1° south of Saturn. The blue-green planet shines at magnitude 5.6 and measures $3.8''$ across.

ASTEROIDS IN THE EYEPiece

On July 2 Vesta lies 2° north of Uranus (see last month's *Through the Eyepiece* for the asteroid's complete path). Vesta's best event, however, occurs on the nights of July 11/12 and 12/13 when the 5.8-magnitude asteroid passes in front of the open cluster M21 (see map on opposite page). M21 is a 6th-magnitude cluster that contains some seventy stars of magnitude 7.3 and fainter. The cluster forms a good background to visually or photographically gauge Vesta's movement.

COMETS FOR THE TELESCOPE

Comet Brorsen-Metcalf should brighten considerably this month and become visible in 6-inch telescopes by month's end. Brorsen-Metcalf begins July as a 12th-magnitude fuzzy "star" in Pisces. As the month progresses, the comet moves northeastward along Pisces' borders with Pegasus and Andromeda and brightens to about 9th magnitude by the end of July. See "Return of a Bright Comet" by Christopher E. Spratt on page 76 for more details on observing 1989's best periodic comet. □



PASSING THROUGH THE PLEIADES on July 27, the crescent Moon occults the cluster for observers in northwestern North America. This view shows the Moon as seen from Vancouver, British Columbia, at 3 a.m. (right) and 5 a.m. (left).

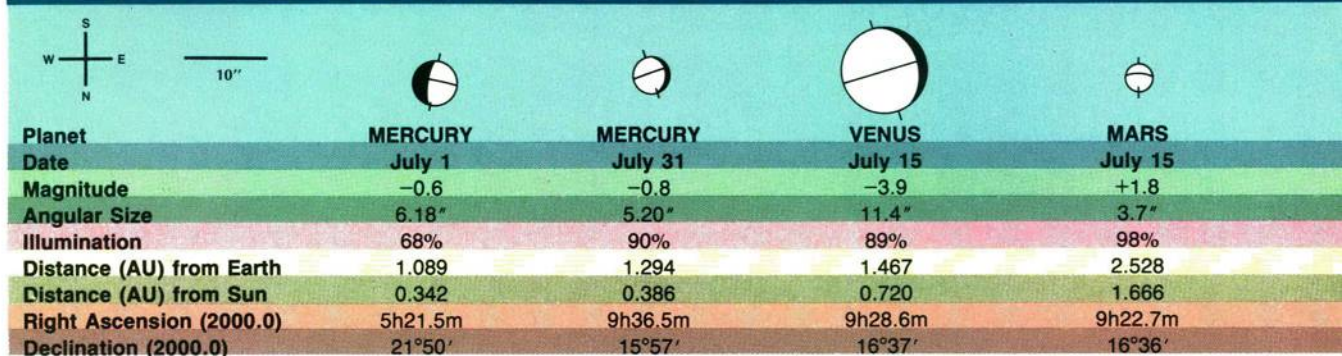
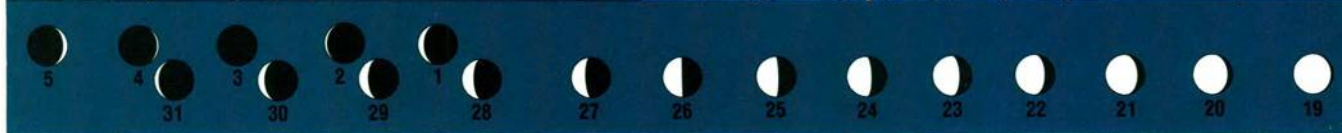
The Moon occults the Pleiades on July 27

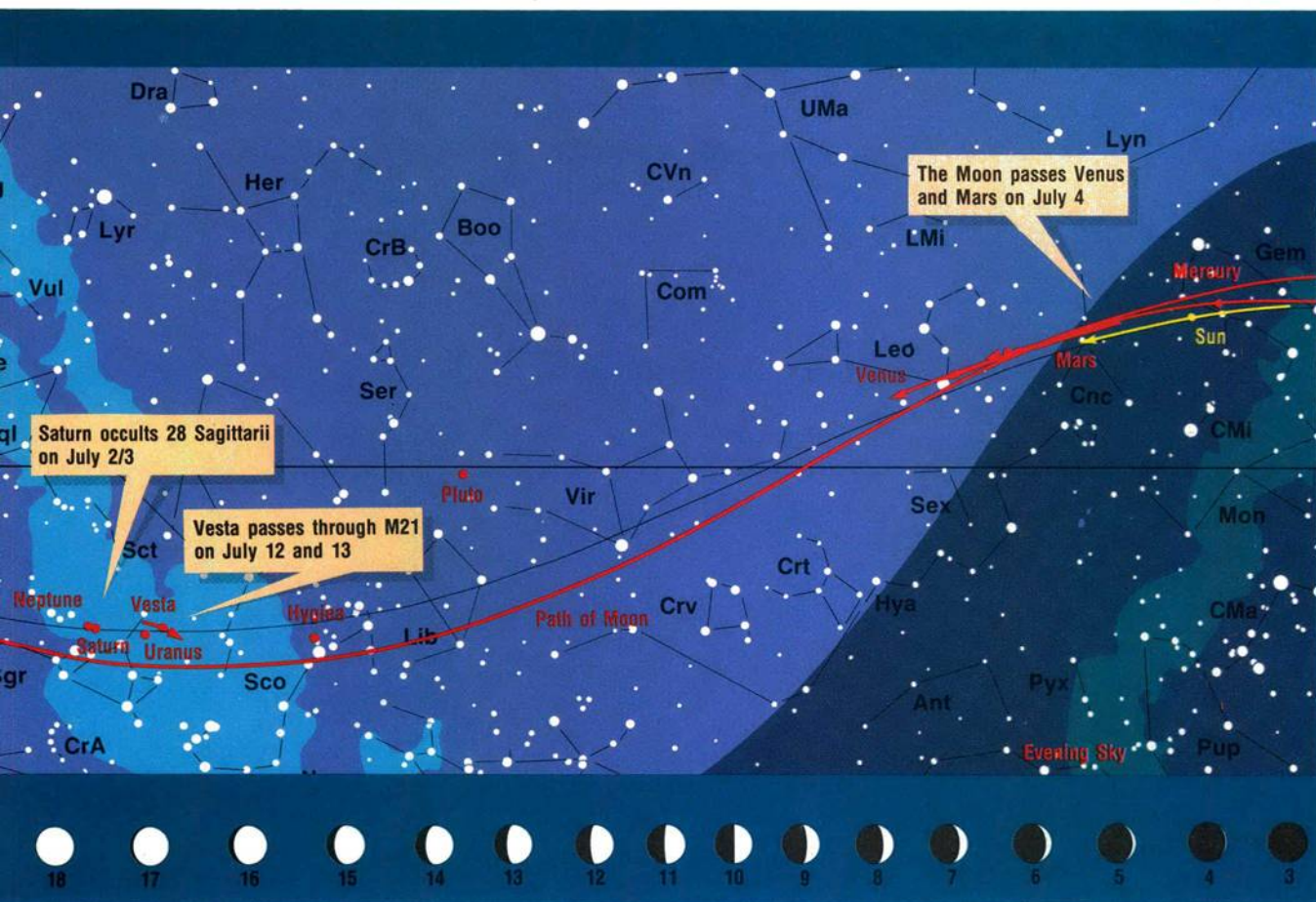
Mercury Jupiter

Comet Brorson Metcalf

Eunomia

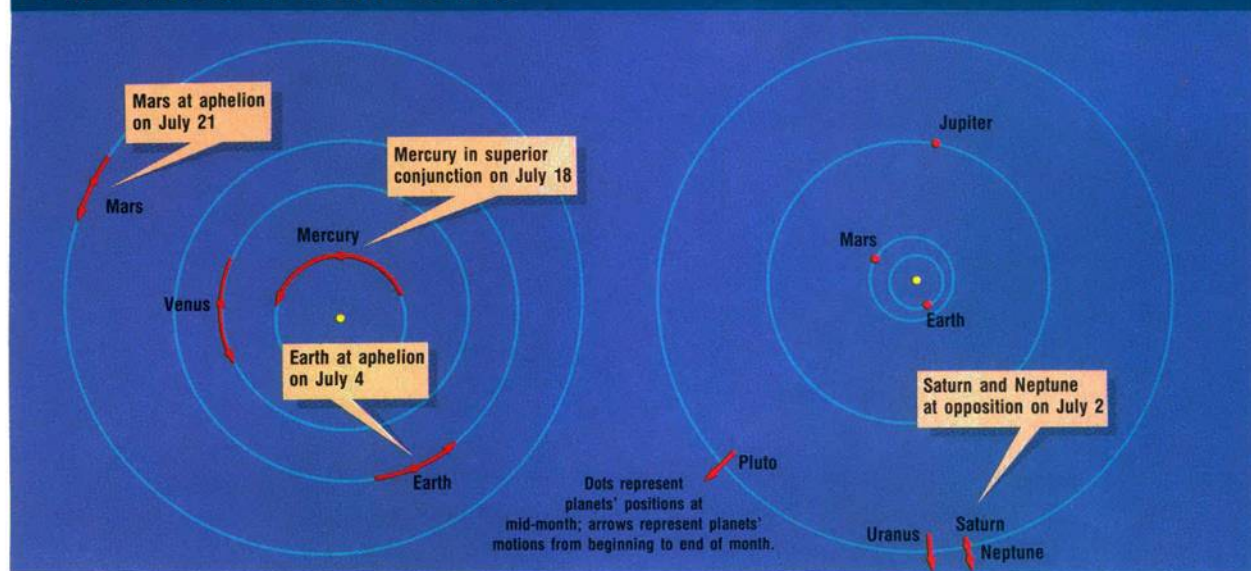
Other labels on the map include: Lyn, Aur, Gem, Per, And, Lac, Cy, Ori, Tau, Ari, Tri, Peg, Del, Sc, Equ, Aqr, Cap, PsA, Mic, Scl, For, Eri, Cae, Col, Pup, CMA, Mon, CMI, Cnc, and the Sun.





JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
July 15	July 15	July 15	July 15	July 15
-2.0	+0.1	+5.6	+7.9	+13.7
32.9"	18.3"	3.8"	2.3"	0.1"
100%	100%	100%	100%	100%
5.987	9.044	18.391	29.219	29.308
5.092	10.037	19.350	30.215	29.656
5h45.9m	18h42.7m	18h11.7m	18h46.7m	14h59.5m
23°03'	-22°29'	-23°41'	-22°04'	-0°24'

The Planets in Their Orbits



Observe the Apollo Landing Sites

With the aid of a telescope and a little imagination, Earth-bound observers can revisit the six sites where men once walked on the Moon.

by Michael T. Kitt

Twelve astronauts left their bootprints on the Moon. Eventually, future astronauts will visit some of the *Apollo* landing sites, just as the *Apollo 12* team piloted next to the *Surveyor* landing site. But it won't be any time soon because there are many other interesting, unexplored places on the Moon that demand attention first.

In the meantime, however, we can visit each of the *Apollo* mission landing sites ourselves, the way amateur and professional astronomers have visited the Moon since the time of Galileo. Unlimber your telescope, be it large or small, and with the help of the accompanying finder maps make your own mission of discovery to the *Apollo* landing sites.

All of the landing sites are visible in a 3-inch telescope, but apertures in the 6- to 8-inch range enable you to resolve some of the finer surface features at each location. For example, an 8-inch telescope and a magnification of 340x will, under good seeing conditions, show craters as small as one mile in diameter, which is equivalent to a naked-eye view from an altitude of 700 miles above the lunar surface. To get a view similar to that of an *Apollo* command pilot orbiting the Moon (about 70 miles above the surface), you'd have to use a magnification of around 3400x under, needless to say, extraordinary seeing conditions!

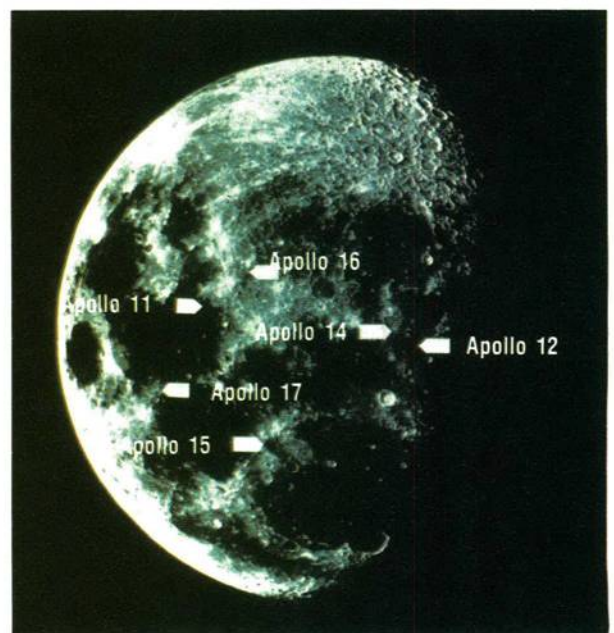
Unfortunately, you can't see any of the lunar hardware left behind by the *Apollo* astronauts. The largest piece is far too small for even the most powerful telescopes to detect. Trying to see the lunar rover from Earth, for example, would be like trying to see a single grain of fine beach sand from a jet at an altitude of five miles. But you *can* see the beach from that altitude; likewise, you should have no trouble getting a sense of the kind of large-scale terrain present at each lunar landing site through the telescope. In addition to sharp-walled craters and craggy mountains, you'll also see ejecta (material thrown out of a meteor crater by the shock of the impact), bright crater rays, canyonlike rilles, wrinkle ridges across otherwise flat plains, and sharp peaks protruding from the center of crater floors.

For orientation purposes, north refers to the "top" of the Moon as seen with the naked eye and in binoculars. In telescopes without a star diagonal, south appears at the "top," with west at the "right" and east at the "left" in the field of view. In tele-

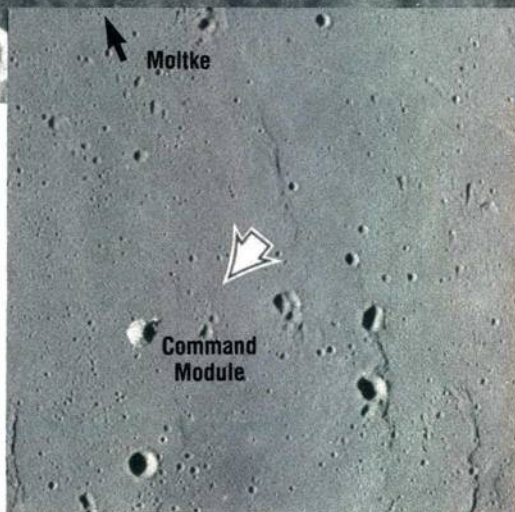
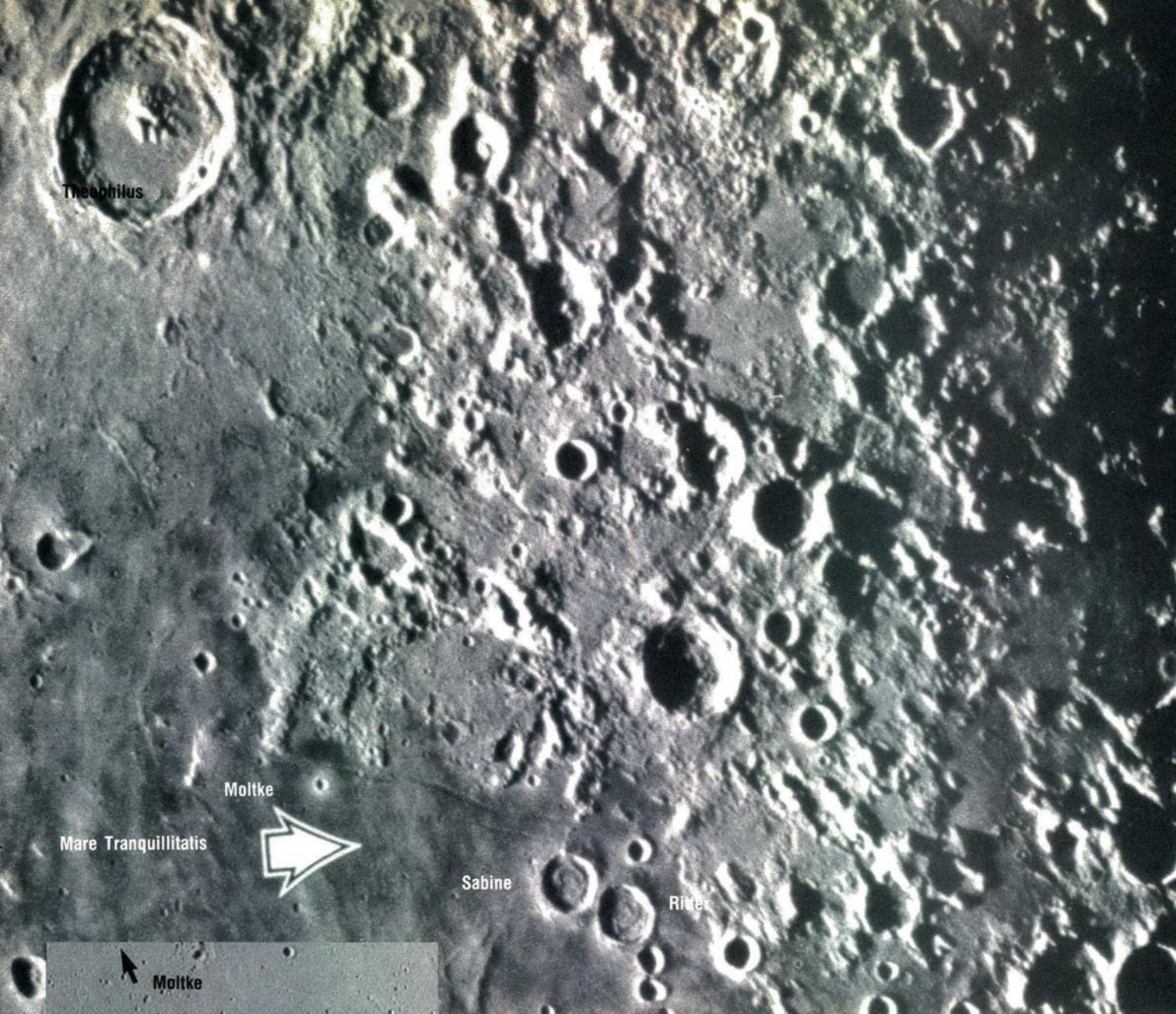
scopes equipped with star diagonals, south remains at the top, but east and west are reversed.

To help you get your bearings, try designating certain prominent features as directional indicators. For example, Mare Crisium, an obvious circular basin seen during the early lunar phases, lies near the Moon's eastern limb. Therefore, it can denote east on the Moon. The distinctive dark-floored crater Plato, seen just after First Quarter, can indicate north because it lies squarely in the northern sector. The bright splash crater Kepler can indicate the western sector (during Gibbous and Full Moon phases), and in the southern hemisphere, the Straight Wall, because it "points" toward the south pole, makes a good southern indicator. □

Michael T. Kitt is a member of the Association of Lunar and Planetary Observers. His most recent article, "Eight Lunar Wonders," appeared in the March 1989 issue.



THE SIX APOLLO LANDING SITES can all be viewed in small telescopes at high magnification.

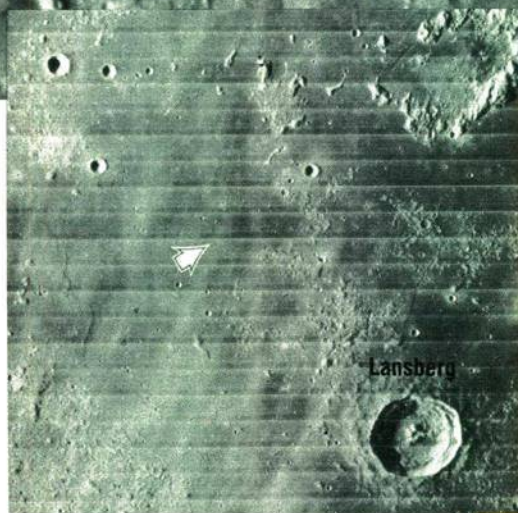
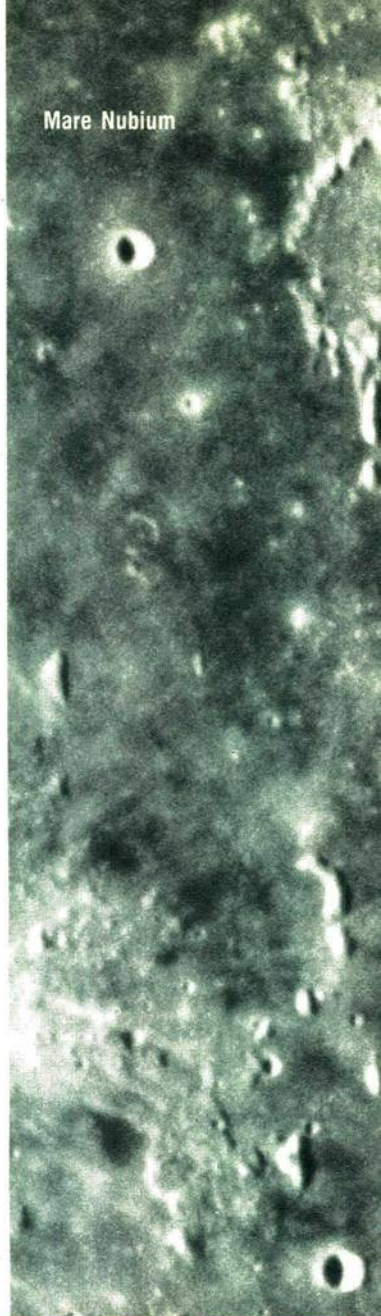


Apollo 11: Tentative First Steps

Because the *Apollo 11* landing site was selected primarily for safety, this area looks pretty bland. The surrounding area, however, has many interesting features that can be best viewed six days after New Moon.

The *Apollo 11* landing site is due east of the crater pair Ritter and Sabine in the southwest corner of the Sea of Tranquility. These craters show obvious signs of alteration by the encroaching lavas that flooded Mare Tranquillitatis over 3 billion years ago. Just to the south is the long rille Rima Hypatia, the most prominent of a vast series of rilles that encircle the Sea of Tranquility on its western edge. North-northwest of the landing site is the fresh crater Arago, which has two very large domes associated with it. One dome is located due west, the other due north; each dome is one crater-diameter away from the crater wall itself.

Tranquility Base is located in a very smooth region, although quite a few wrinkle ridges (irregular linear "folds" in the surface) can be seen crossing the mare floor in extreme low-angle light. Observers with 8- to 10-inch scopes will enjoy looking for three craterlets running in a straight line just north of Tranquility Base. These are named (from east to west) Armstrong, Collins, and Aldrin, in honor of the *Apollo 11* astronauts.



Apollo 12: A Pinpoint Landing

The second lunar mission had two main purposes. The first was to demonstrate the ability of the lunar lander to make precision landings by coming down close to the resting spot of *Surveyor 3*, which had been placed on the Moon 30 months earlier. *Apollo 12* landed about 600 feet away from *Surveyor* (the mission team stated that they could have landed right next to it if they had wanted to). The other goal of the mission was to obtain samples of debris splashed out of the great crater Copernicus, located a little over two hundred miles to the northeast.

The *Apollo 12* landing site is located about a third of the way from the crater Lansberg (noted for its prominent central peak) to the large, ill-defined crater Fra Mauro on the southeast edge of the vast Oceanus Procellarum. The site is best viewed nine days after New Moon.

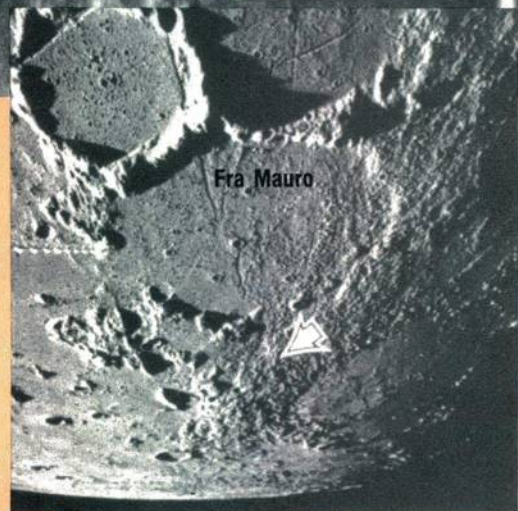
Although this area is seemingly uninteresting when viewed through a telescope, it contains many geologically interesting features, thus it is one of the most explored areas of the Moon. In addition to *Surveyor 3*, crash landings of *Ranger 7* and *Luna 5* took place here in the mid-1960s, and *Apollo 14* landed only 80 miles to the east. This region of Oceanus Procellarum was renamed Mare Insularum, the Island Sea, in 1970.

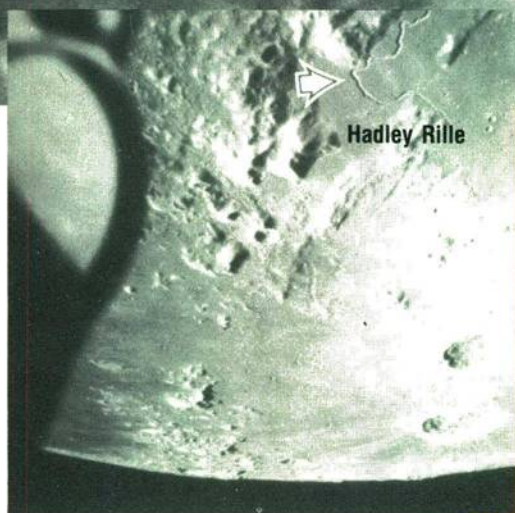


Apollo 14: Fra Mauro Adventure

Apollo 14 landed in the hills at the northern edge of the crater Fra Mauro. This was the first attempt at landing in less than extremely gentle terrain, and it paved the way for the daring final three missions. This mission could have been subtitled "How to Get Lost on the Moon." Gently rolling hills and a profusion of small craters made orientation on the surface very difficult. The astronauts were unable to locate the 1,200-foot-wide Cone crater, a major objective of the second excursion. Later analysis showed they were actually within 50 feet of the rim of this crater, but were unable to recognize it.

The area immediately to the south of the landing site contains the ancient craters Fra Mauro, Bonpland, and Parry nestled together. Their floors have been inundated with lava and their rims are battered and broken in many places. A system of fine rilles runs north-to-south within this crater complex; the largest of these rilles can be seen to cut through the crater wall between Fra Mauro and Parry. This area can best be observed nine days after New Moon.





Apollo 15: Looking into a Rille

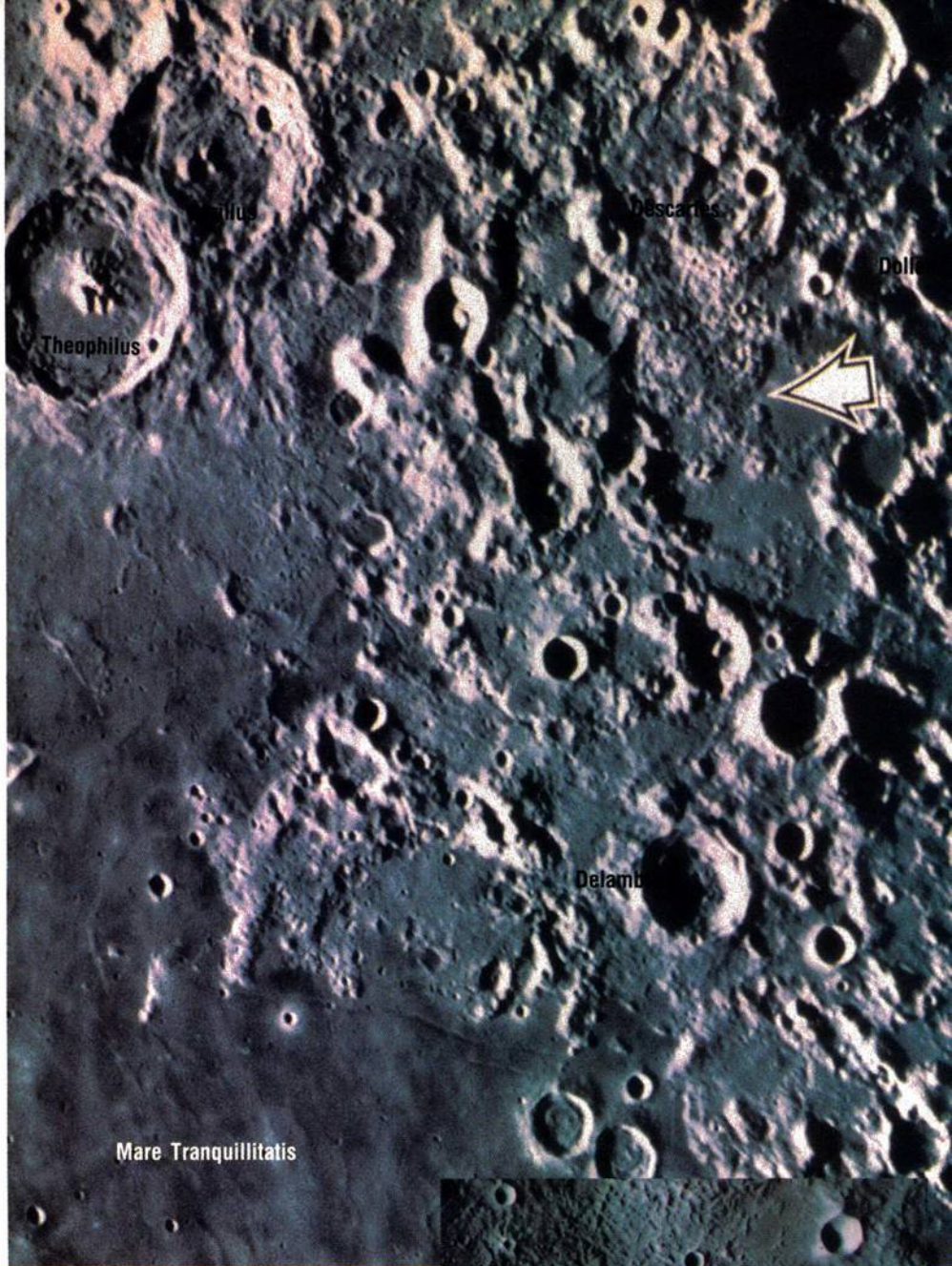
The *Apollo 15* landing site at the base of the Apennine Mountains in the north-central section of the Moon is easy to locate with a small telescope a day or two after First Quarter Moon and a day or two before Last Quarter Moon, when the surface features stand out in the low-angle light. The Apennine Mountains lie at the juncture of Mare Imbrium, Mare Serenitatis, and Mare Vaporum. Mount Hadley is the first major peak on the northeast end of the Apennines. Immediately south of Mount Hadley is a squarish-shaped valley; it was within this valley that *Apollo 15* landed.

The famous Hadley Rille, which crosses the valley, requires good seeing and a 6- to 8-inch telescope at moderate power to see. It lies immediately to the west of the Apennines; thus at First Quarter Moon it is hidden in the shadow of these mountains for a while after local sunrise.

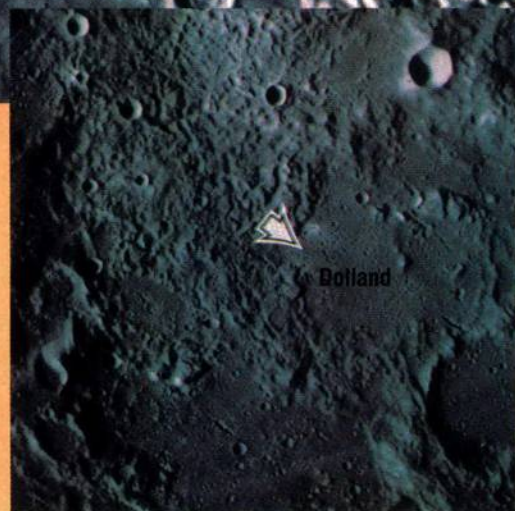
The best way to spot this very fine rille is to first locate the 3-mile-diameter, bowl-shaped crater Hadley, which is slightly south of the landing area. It is the only crater in the vicinity. Hadley Rille snakes around this crater and meanders northward until it reaches the landing area, where it makes an abrupt turn to the northwest, forming an elbow. It is at this elbow that astronauts Scott and Irwin stood and stared into this chasm.



Mare Imbrium



Mare Tranquillitatis



Doland

Apollo 16: Daring Highlands Mission

This site in the lunar highlands is the most difficult of the six landing sites to locate, even for an experienced lunar observer. Yet once you identify certain features, you can easily pinpoint it.

To find the *Apollo 16* landing site, wait until a day before First Quarter Moon and use a variation of "star hopping." The first step is to locate the prominent crater Theophilus on the western banks of Mare Nectaris. This magnificent crater has sharp, terraced rims and three central peaks on its floor. The crater Descartes is exactly three Theophilus-diameters due west of Theophilus' western wall. Easier to spot will be the sharply-defined bowl crater Descartes A, which sits atop the crumbled wall of Descartes itself.

Six miles to the northwest of Descartes A is another bowl crater, Doland. These are the only two craters with sharp rims in the vicinity. Using the photo above, construct a mental isosceles triangle: the *Apollo* site marks the north point and lies in a relatively smooth area. If you can identify this area at Full Moon, you will be able to spot the bright splash pattern of South Ray crater, sampled by the astronauts and found to be only 2 million years old, extremely fresh for a crater of this size.



Apollo 17: In Search of Volcanoes

The final *Apollo* landing site is extremely easy to find if you know what to look for. The Taurus-Littrow Valley is located on the perimeter of Mare Serenitatis along the southeast edge. This small area is one of the darkest regions on the Moon, but it stands out at Full Moon. Lunar scientists were convinced that the dark color was evidence of recent volcanism. Unfortunately, they were wrong. Samples from Taurus-Littrow were in the same age range — about 3.86 billion years — as samples from the other five sites. One very interesting result of this mission was the discovery that many craters on the floor of this valley were formed by the Tycho impact some 109 million years ago. Tycho crater, located 1,400 miles to the southwest, is the center of the Moon's greatest ray system.

Having located the landing site at Full Moon, you'll want to revisit it five days later when the Sun is setting in that area, and everything is thrown into sharp relief. First note that the Taurus-Littrow Valley is immediately due east of an area where the ring of Mare Serenitatis is broken and connects with Mare Tranquillitatis to the south. In the grazing sunset light you'll note that this valley is markedly squarish. With larger instruments you may see the bright landslide that the astronauts visited.

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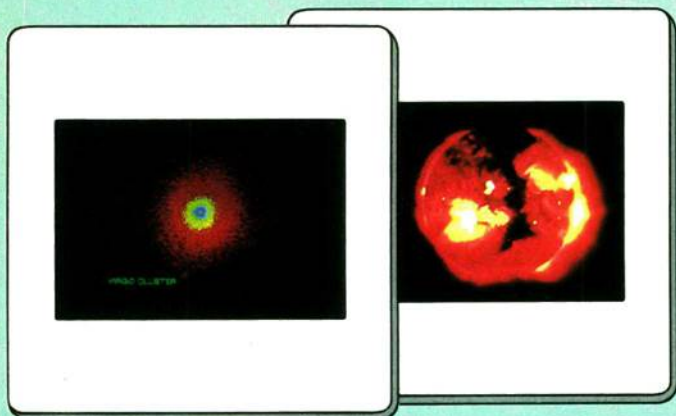
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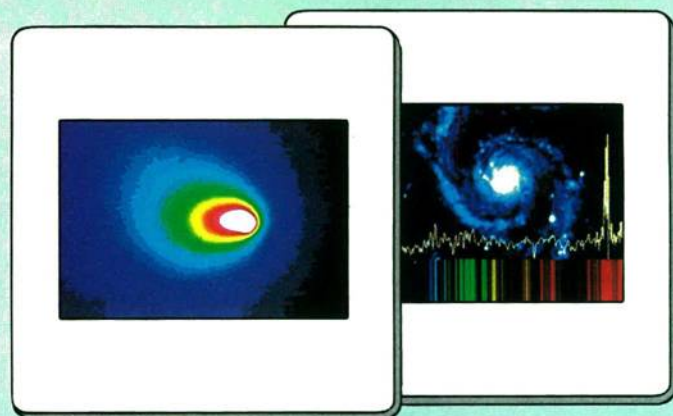
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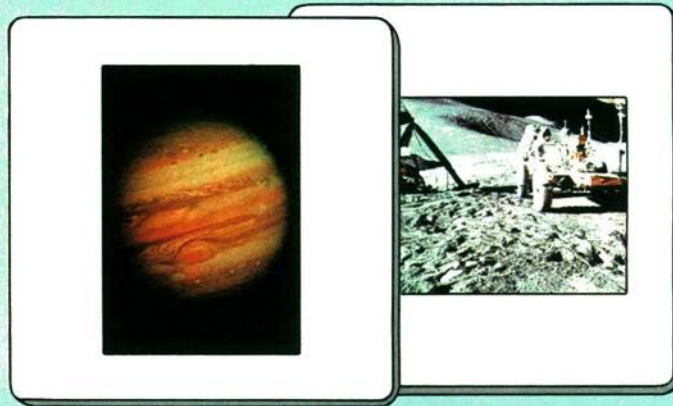
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Return of a Bright Comet

Comet Brorsen-Metcalf may rival Halley as the comet grows brighter in the morning sky this summer.

by Christopher E. Spratt

The brightest periodic comet to visit the inner solar system since Comet Halley is rushing toward a rendezvous with Earth late this summer. Already visible to backyard observers with large telescopes, Comet Brorsen-Metcalf will brighten rapidly over the next few months and should reach naked-eye visibility in September.

This apparition looks particularly favorable for Northern Hemisphere observers. During July and August Comet Brorsen-Metcalf will appear high in the sky and should be bright enough to see with a 6-inch telescope under a dark sky. By late August the comet will be easy to spot in binoculars.

Comet Brorsen-Metcalf remains in the morning sky throughout this apparition, which means the best times to observe the comet are from a few days before New Moon to ten days after New Moon. If you own an 8-inch telescope, you can start looking for Brorsen-Metcalf now. In early June the comet is near the border of Aquarius and Pisces and glowing dimly at 14th magnitude.

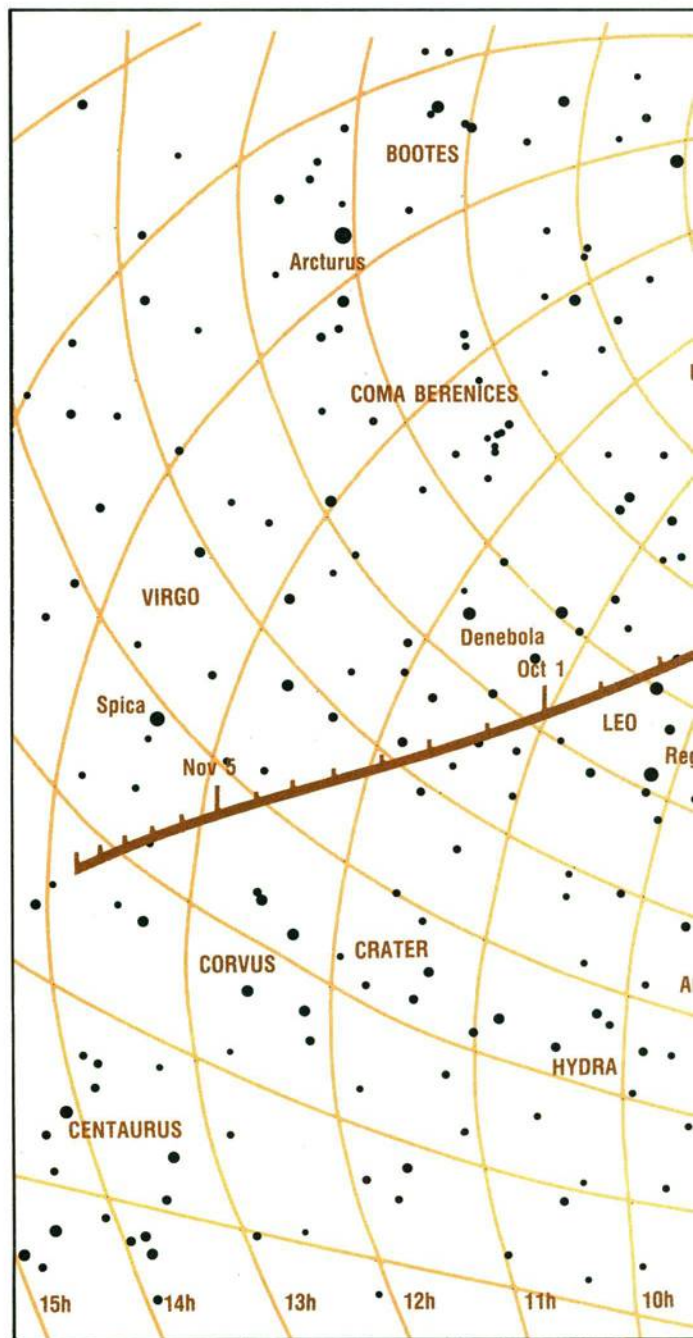
At New Moon on July 3 the comet is in western Pisces and located about 50° above the south-southeast horizon as morning twilight begins. By August 1's New Moon the comet shines at 9th magnitude in northern Pisces. It is high in the southeast shortly after midnight and passes just 10° from the zenith as dawn breaks.

The best observing "window" for Brorsen-Metcalf is from late August to early September, between the time it is closest to Earth and closest to the Sun (late September). The 6th- or 7th-magnitude comet lies in the relatively barren constellation Lynx and appears 30° to 45° high in the northeast as morning twilight begins.

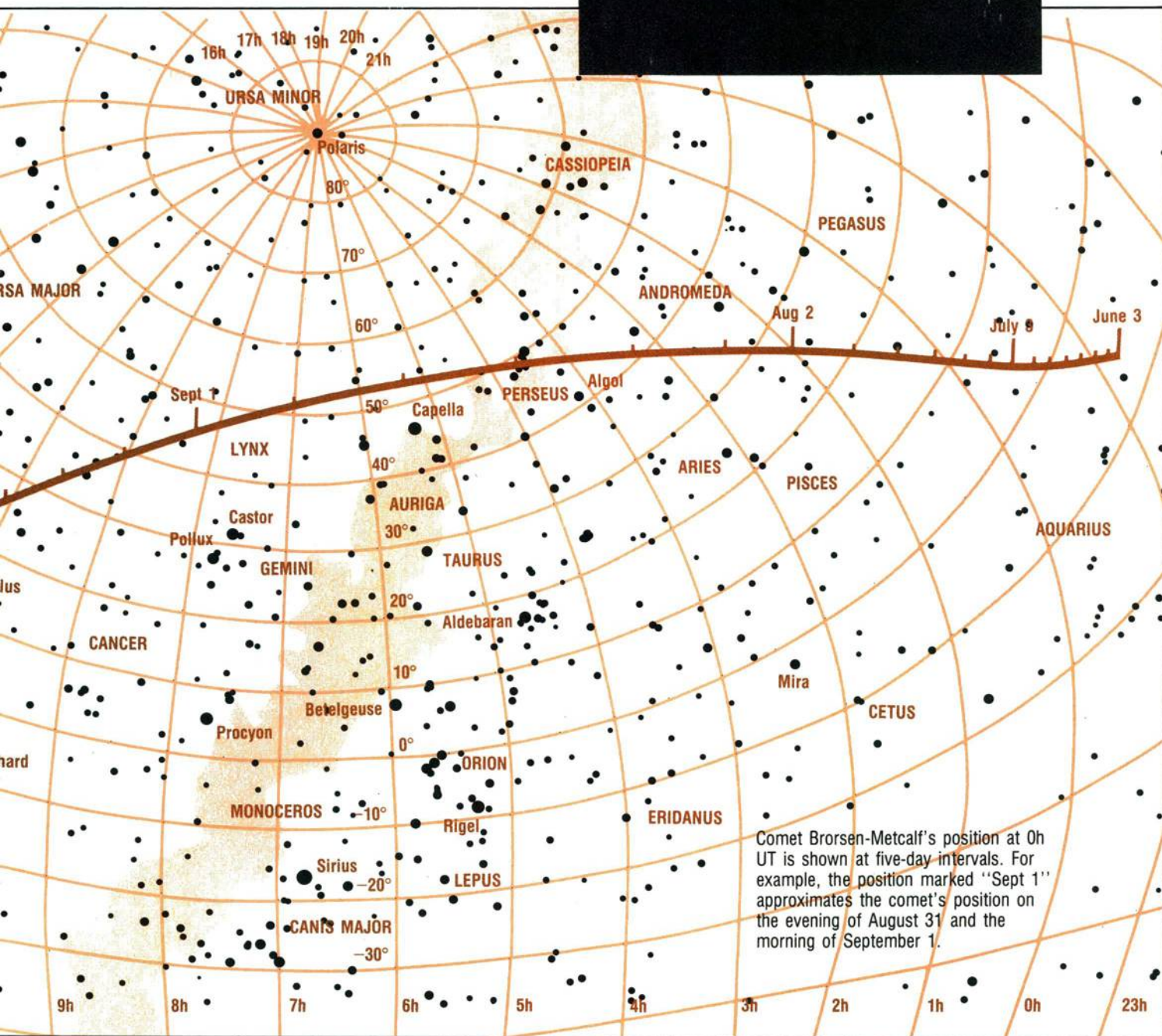
Although Brorsen-Metcalf reaches 5th magnitude in late September, by then the comet is much closer to the Sun and harder to see. It has moved south into Leo and appears about 15° high in the east at daybreak.

After its closest approach to the Sun, the comet becomes more difficult to see. It is a 9th-magnitude object in late October and fades to 12th-magnitude a month later. By December Comet Brorsen-Metcalf will have faded from view for observers in mid-northern latitudes, but the memories of this apparition should remain bright for a long time to come. □

Christopher E. Spratt lives in Victoria, British Columbia, where he pursues his astronomical interests, visually observing comets and variable stars.



COMET BRORSEN-METCALF last passed near Earth in 1919, when it glowed at magnitude 4.5 and sported a tail 8° long. Early predictions indicate the 1989 apparition should be nearly as favorable.



Comet Brorsen-Metcalf's position at 0h UT is shown at five-day intervals. For example, the position marked "Sept 1" approximates the comet's position on the evening of August 31 and the morning of September 1.

The Ten Best Double Stars

An endless variety of colors and brightnesses in these stellar pairs guarantees year-round observing enjoyment for small-scope owners.

by Phil Harrington

Shimmering with starlight, the night sky glows with the light from numerous, solitary stars. However, these seemingly single points of light often consist of two or more stars. In fact, over half the stars in our Galaxy, and probably elsewhere in the universe, belong to double or multiple star systems. The illusion of a night sky filled with single stars exists because the pairs are too close together and too distant to be resolved by eye alone.

A small telescope reveals a multitude of double and multiple stars spread across the sky. These objects are captivating to observe because each one provides a different combination of star colors, brightnesses, orientations, and separations between component stars. The almost endless variety of double and multiple stars and easy availability of specimens on any night of the year make double star observing one of the most satisfying pursuits with a small telescope.

Some double stars are "fixed," meaning their components have not moved since their discovery. However, most double stars do show orbital motion over time. The result is that secondary stars appear at different positions as they orbit the primary stars. Some stars show motion over a few years, while others take decades to change relative positions.

To keep track of the positions of double-star components, astronomers use a measure called position angle. Position angle is the angle between the two stars measured from 0° to 360° in an easterly direction from north. The tricky part of interpreting position angles is remembering which orientation your telescope's field provides. The standard view with a reflector and a straight-through eyepiece yields a field of view with south at the top and east at the right. An easy way to remember position angles for this configuration is to imagine a clock face with the primary star at the center. North (0°) is at six o'clock, east (90°) at three o'clock, south (180°) at twelve o'clock, and west (270°) at nine o'clock. For example, Albireo has a position angle of 54°, so the bluish secondary lies northeast of the yellow primary.

However, if you insert a star diagonal into the telescope's optical system, you'll reverse the image left-right, and position angles become somewhat trickier to interpret. The best method of interpreting position angles is to confidently determine directions in the sky. It's reasonably easy with an equatorial mounting that moves along axes of north and south, east and west. North is

toward the North Star, Polaris, and stars appear to trail toward the west. It's somewhat trickier if you have an altazimuth mounting. If you're confused, let the stars drift to show east and west, then converting directions in your mind is easy.

Of all the double stars in the sky, none is more attractive than **Albireo** (Beta [β] Cygni). To the naked eye, this star is a 3rd-magnitude point of light marking the nose of the Swan in Cygnus. A low-power view through binoculars or a finder scope reveals that Albireo is actually a pair of stars set in a densely packed field of faint stars. Albireo is one of the most beautiful sights in the heavens, appearing like two jewels separated by a gap of inky black space.

A 3-inch scope at 30x shows the stars' colors nicely. The primary (brightest) star is a magnitude 3.1 star that appears strongly yellow. Its companion, located 34" away, is a 5th-magnitude star with a decidedly bluish tint. Because Albireo lies 410 light-years away, the 34" distance between the two stars translates to 4,400 astronomical units, or about 400 billion miles.

Albireo is an example of a binary star, which means its components are physically bound stars that orbit each other and travel about the Galaxy as a pair. When the German double star observer Friedrich Georg Wilhelm Struve first examined Albireo in 1832, he measured the distance between the component stars as 34". Albireo is also a fixed pair: the orientation of the stars has not changed at all since Struve's measurement.

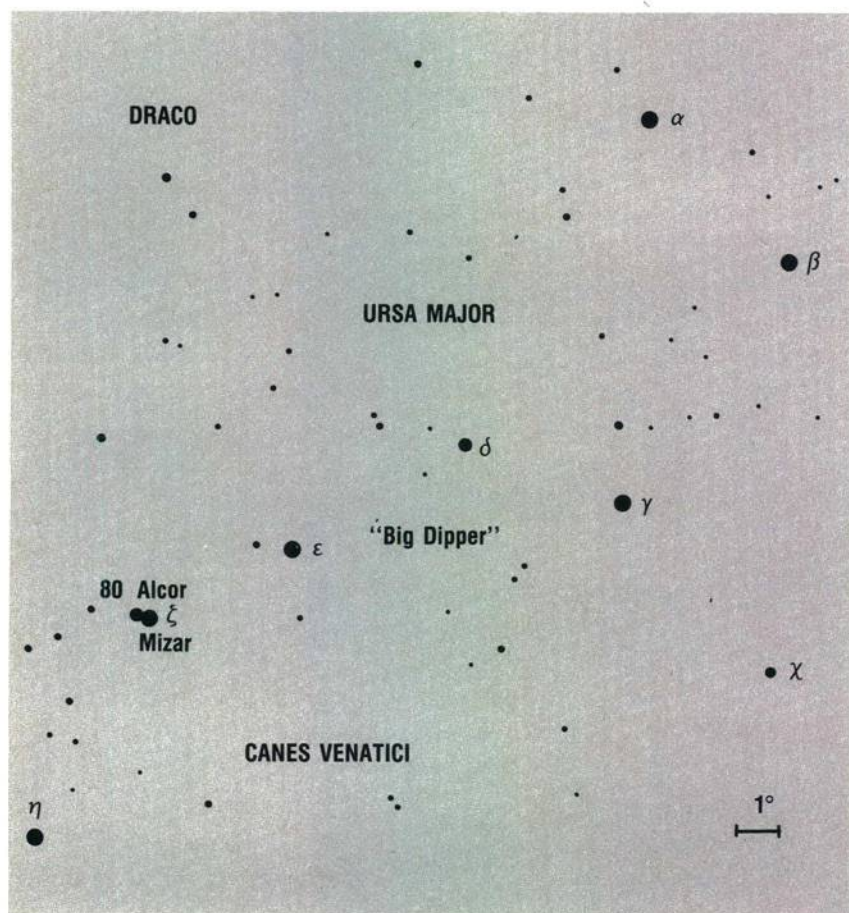
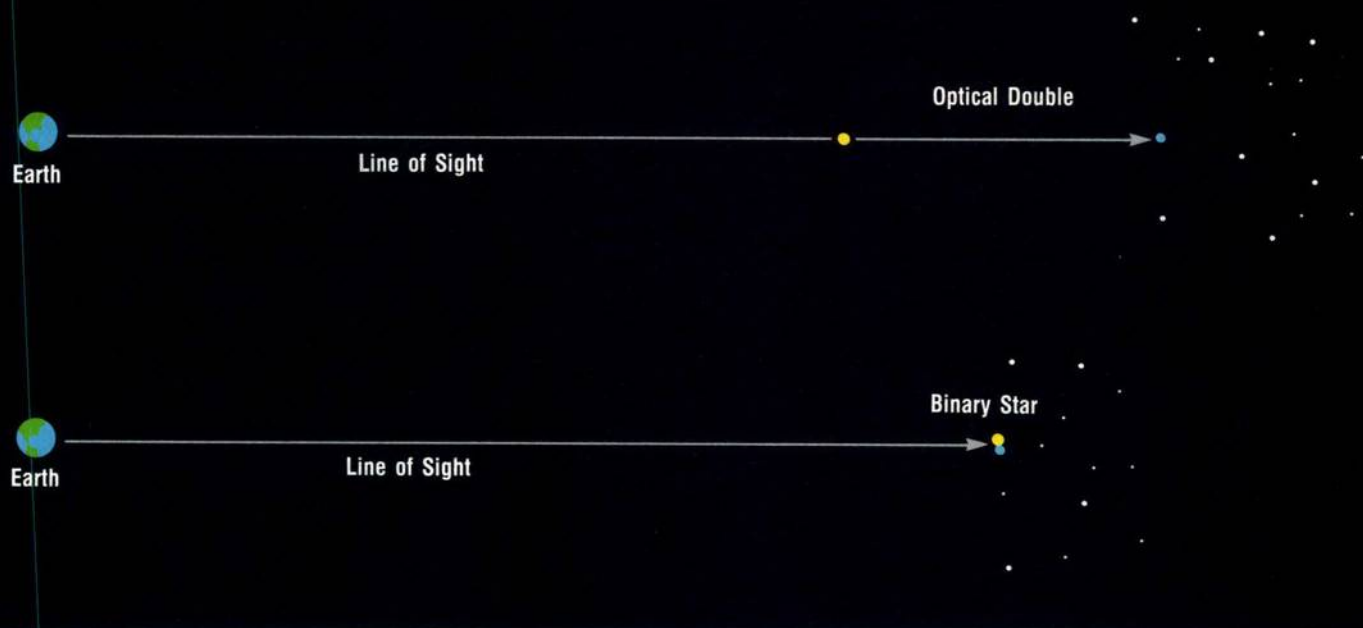
Not all double stars are binaries, however. Another class of stars, optical doubles, are simply chance alignments of stars lying at different distances that appear close together in the sky.

The best-known optical double in the sky is formed by **Mizar** (Zeta [ζ] Ursae Majoris) and **Alcor** (80 Ursae Majoris). The pair is easy to find because Mizar marks the bend in the handle of the Big Dipper. Alcor and Mizar are in a chance alignment. Mizar lies 82 light-years distant, and Alcor (the foreground star) is 60 light-years away. However, Mizar itself is a binary star. In fact it was the first double star discovered with a telescope (in 1650 by the Italian astronomer Giovanni Battista Riccioli).

Since its discovery, Mizar's components have moved only about 10° in position angle. The stark, white primary star shines at magnitude 2.4 and its companion, glowing with a similar hue, lies 14" southeast. The secondary has a magnitude of 4.0. In any telescope the stars

OPTICAL DOUBLES AND BINARY STARS

Over half of the stars in the sky are double or multiple stars. However, many stars that appear as doubles are not gravitationally linked to each other but lie at different distances along the same line of sight. These are optical doubles. Binary stars are "true" doubles because they orbit about a common center of mass. For example, Alcor and Mizar mark the middle of the Big Dipper's handle and form a close naked-eye double. They are physically unrelated. However, as a high-power telescopic view shows, Mizar is itself a binary star consisting of two bright white stars.



ALCOR AND MIZAR
2.5-inch f/10 Reflector at 80x
by Glenn F. Chaple, Jr.



MIZAR
8-inch f/10 SCT at 170x
by David J. Eicher

A CLOSE NAKED-EYE PAIR, Alcor and Mizar mark the bend in the handle of the Big Dipper. Mizar is itself a close binary composed of gleaming white stars shining at magnitudes 2.4 and 4.0.

THE SKY'S BEST DOUBLE STARS

From Albireo to Xi Bootis, the sky's finest double stars offer a wide range of colors, brightnesses, and separations. The first nine stars are shown as they appear in a telescope, with south at the top and west at the left. The scale is 1" per inch. Position angles are indicated for each pair. Position angle is the angle between the stars measured from 0° to 360° in an easterly direction from north.

Albireo
Separation 34.4"
Position angle 54°



South is up, west is left

Mizar
Separation 14.4"
Position angle 152°



Delta Corvi
Separation 24.2"
Position angle 214°



Xi Bootis
Separations 7" and 66.7"
Position angles 310° and 348°



Nu Draconis
Separation 61.9"
Position angle 312°



Beta Scorpii
Separation 13.6"
Position angle 21°



Gamma Arietis
Separation 7.8"
Position angle 0°



Gamma Andromedae
Separation 9.8"
Position angle 63°



Theta¹ Orionis
Separations 8.8", 12.8", and 21.5"
Position angles 31°, 132°, and 96°



Epsilon Lyrae
Separation 208"
Position angle 173°
(ε¹ to ε²)



Scale is 30" per inch

East is up, south is left

form a striking pair.

Mizar's lack of color makes it appear quite different from Albireo. Occasionally, however, observers note a tinge of color in Mizar's stars. Author R. H. Allen sees them as "brilliant white and pale emerald." The nineteenth-century observer Thomas W. Webb called the stars "greenish-white." How do you perceive the stars' colors?

A more colorful double star lies in the southern constellation Corvus the Crow. This star group's distinctive trapezoidal pattern makes it easy to locate. **Delta (δ) Corvi**, also known as Algorab, marks the northwest corner of the trapezoid. To the naked eye, this star is a single, 3rd-magnitude point of light. However, as John Herschel and James South discovered in 1823, Delta Corvi shows a magnitude 3.0 primary and magnitude 9.2 secondary when viewed through a telescope. The companion star lies slightly more than 24" southwest of the primary. The stars in this pair softly glow with yellow and lilac hues.

Larger, brighter, and higher in the sky, the constellation Bootes contains an impressive multiple star for springtime nights. **Xi (ξ) Bootis**, discovered in 1780 by William Herschel, lies 8° east of brilliant Arcturus, the constellation's brightest star.

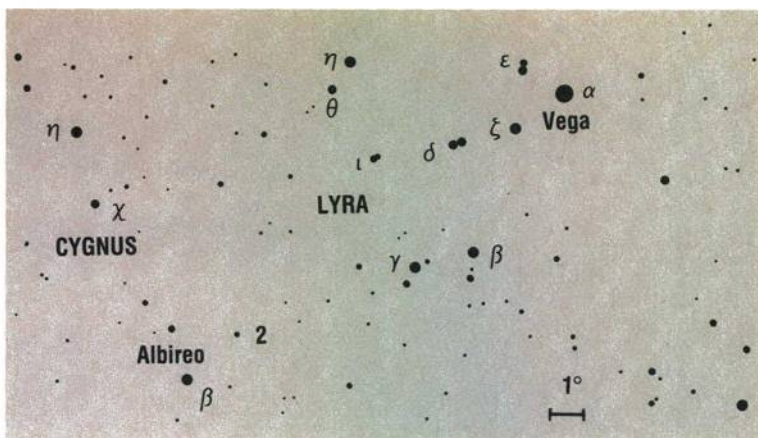
Xi Bootis is a star for all telescopes. Small instruments show it consisting of magnitude 4.7 and 7.0 components currently separated by about 7" with a position angle of 310°. Large scopes reveal two other components: a magnitude 12.6 star some 67" away and a 10th-magnitude orb located nearly 150" from the primary.

The colors in the Xi Bootis system are breathtaking. The 5th-magnitude primary is strongly yellow, and the 7th-magnitude secondary star is vividly reddish orange. Viewing the two stars, tightly embraced and surrounded by a rich field strewn with stars, is an unforgettable observing experience.

Nu (ν) Draconis is another dramatic springtime double star. The faintest of the four stars that form the trapezoid of Draco's head, Nu Draconis is one of the easiest binaries in the sky to resolve. Its twin 5th-magnitude stars are separated by about 62", making them visible as a pair through finder scopes and low-power binoculars. Most observers see these stars as pure white in color, which agrees with their spectral type of A. Astronomers have measured the distance to Nu Draconis as 120 light years, which places the stars' actual separation at 2,300 astronomical units.

As the springtime night sets in the west, summer's binary stars become visible in the east. Second only to Albireo in popularity among these stars is **Epsilon (ε) Lyrae**. Nicknamed the Double-double, Epsilon Lyrae is the sky's most spectacular quadruple star. Epsilon lies slightly northeast of dazzling Vega and is faintly visible to the naked eye as a single point of light. Sharp-eyed observers can resolve Epsilon into a pair of 5th-magnitude stars using no optical aid at all. On the next dark night, try doing this yourself.

The northernmost of the 5th-magnitude stars is Epsilon¹ Lyrae, which lies 208" away from Epsilon². Whether or not you can resolve Epsilon Lyrae with the naked eye, try looking at either Epsilon¹ or Epsilon² with at least a 3-inch scope at about 100x. Wait for a night when the air is steady and the stars barely twinkle. If the seeing is good, you will see that each of the stars is itself



THE PRETTIEST PAIR in the sky, Albireo's golden yellow and blue stars are visible in a 3-inch telescope at low power. The star marks the nose of Cygnus the Swan.

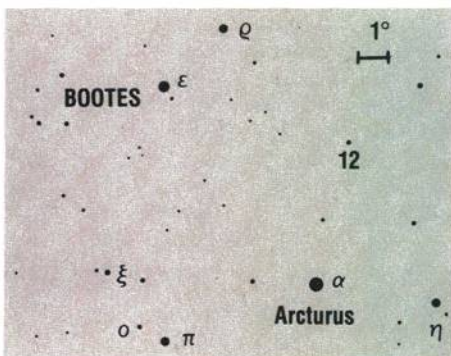
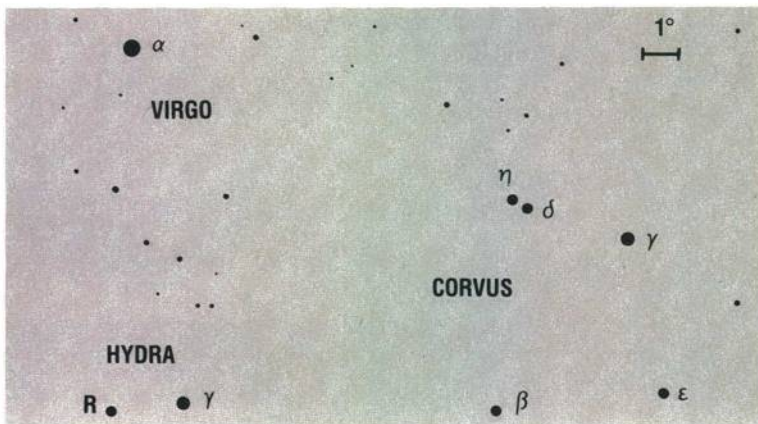


ALBIREO
4.25-inch f/4 Reflector at 48x
by Debra J. Williams



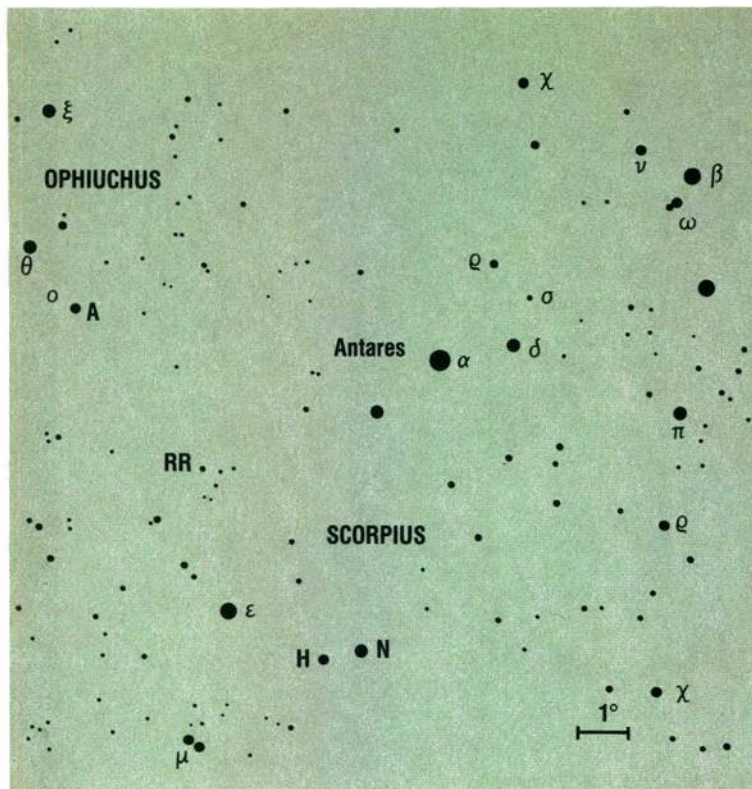
DELTA CORVI
4.25-inch f/4 Reflector at 48x
by Debra J. Williams

PALE VIOLET and yellow, the stars of Delta Corvi offer a stark contrast. The secondary is hard to see because the primary is so bright.



XI BOOTIS
3-inch f/10 Reflector at 60x
by Glenn F. Chaple, Jr.

A TRIO OF STARS makes up Xi Bootis. A close pair of 5th- and 7th-magnitude stars offer yellow and burnt orange colors visible in any telescope. The third star, a 12th-magnitude orb, lies over 1' away from the primary.



BETA SCORPII is the second brightest star in Scorpius and one of the sky's best double stars. Easily resolved with any telescope, this pair offers two bright white stars separated by 13.6".

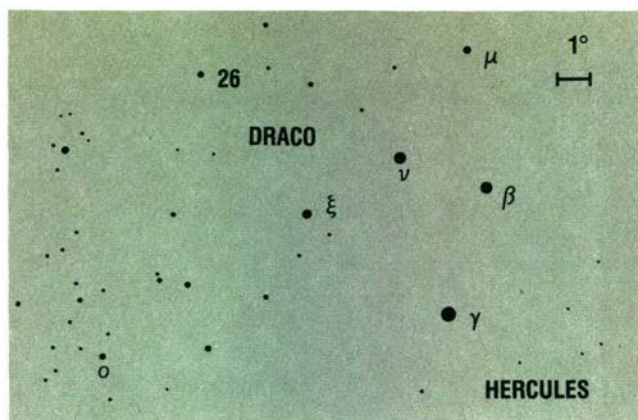


BETA SCORPII
4.25-inch f/4 Reflector at 48x
by Debra J. Williams

a double.

Epsilon¹ consists of a 6th-magnitude secondary star orbiting a 5th-magnitude primary once every 1,165 years. Over 150 astronomical units actually separate the stars, which corresponds to 2.6" in the sky. Observers with keen perception may detect pale colors in the two components of Epsilon¹ Lyrae. For instance, F. G. W. Struve recorded them as faintly greenish and bluish. However, most observers, both past and present, see them as white points of light.

The southern pair, Epsilon², is a bit tighter than Epsilon¹, therefore, slightly more difficult to resolve. Separated by 2.3", the magnitude 5.5 secondary lies due east of the magnitude 5.2 primary. As with Epsilon¹, these stars lie over 150 astronomical units apart in space. However, the star's orbital period of about 585 years is half that of Epsilon¹.



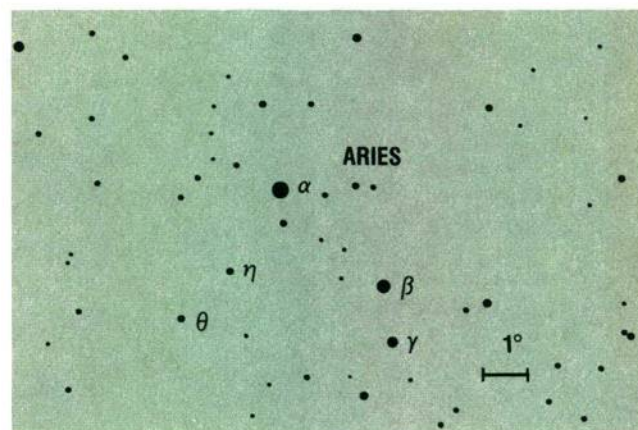
NU DRACONIS
4.25-inch f/4 Reflector at 48x
by Debra J. Williams

THE WIDE PAIR Nu Draconis shows two stars in any telescope or even binoculars.



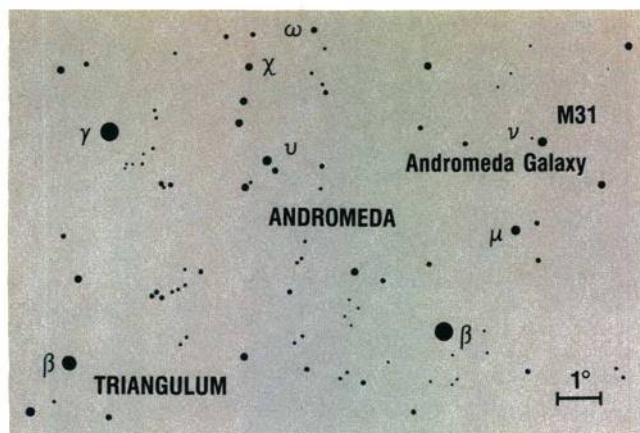
GAMMA ARIETIS
3-inch f/10 Reflector at 60x
by Glenn F. Chaple, Jr.

HEADLIGHTS ON THE SKY, the stars of Gamma Arietis shine with equal intensity.



Follow the gleaming arch of the Milky Way south to Scorpius, one of summer's brightest constellations. Marking the tip of the Scorpion's northern claw is **Beta (β) Scorpii**, one of the season's finest double stars. Even the smallest telescopes have little trouble resolving the magnitude 2.6 and 4.9 components. Separated by 13.6", the secondary lies northeast of the primary. Some observers see colors in the stars, usually noted as "pale yellow and greenish" or "white and lilac." Most observers simply see both stars as white. A mere 0.5" from the primary lies a third component, dimly glowing at magnitude 10.3. This star is a difficult test for a 10-inch scope and is visible only on the steadiest of nights.

It's easy to lose track of time on warm, summer nights. Before you know it, midnight slips away and the summertime star groups are being replaced by autumn's offerings. Of the many attractive binaries scattered



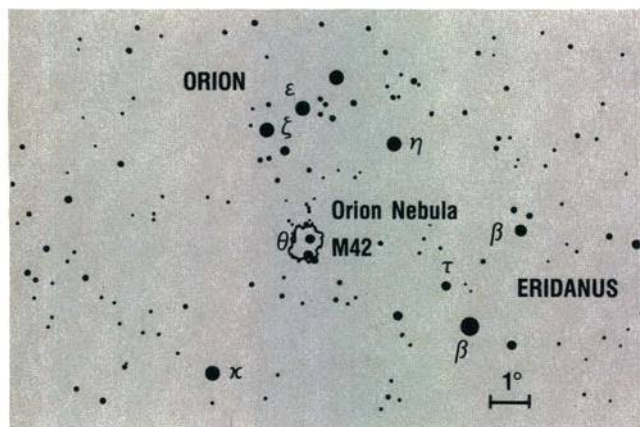
GAMMA ANDROMEDAE
3-inch f/10 Reflector at 60x
by Glenn F. Chaple, Jr.

PRETTY BLUE AND YELLOW stars give Gamma Andromedae a stunning appearance that rivals Albireo.



THETA 1 ORIONIS
3-inch f/10 Reflector at 30x
by Glenn F. Chaple, Jr.

THE HEART of the Orion Nebula is home to Theta 1 Orionis, the finest multiple star in the sky.



throughout the autumn sky, three are especially noteworthy.

Gamma (γ) Arietis, also known as Mesarthim, is easily visible to the naked eye. It is the faintest and southernmost of the three brightest stars in Aries. Gamma Arietis was one of the first known double stars, discovered by Robert Hooke in 1664. Gamma Arietis consists of two identical, pearly white magnitude 4.8 stars separated by 7.8". The position angle for this pair is 0°, which indicates that they are positioned in a line oriented exactly north-south. The stars haven't changed position since F. G. W. Struve measured them in 1830.

Another brilliant binary is **Gamma (γ) Andromedae**, the star marking the princess Andromeda's left foot. Its magnitude 2.3 primary radiates a strong yellow gleam, while the magnitude 5.4 secondary glows with a cool, deep blue light. In 1842, F. G. W. Struve discovered that

The Sky's Best Double Stars

Object	R.A.(2000.0)	Dec.	Mags.	Sep.	P.A.
Gamma Arietis	1h53.5m	+19°18'	4.8, 4.8	7.8"	0° (1969)
Gamma Andromedae	2h03.9m	+42°20'	2.3, 5.4	9.8"	63° (1967)
Theta 1 Orionis	5h35.3m	-05°23'	6.7, 7.9	8.8"	31° (1975)
			5.1	12.8"	132° (1975)
			6.7	21.5"	96° (1975)
Delta Corvi	12h29.9m	-16°31'	3.0, 9.2	24.2"	214° (1958)
Mizar	13h23.9m	+54°56'	2.3, 4.0	14.4"	152° (1977)
Xi Bootis	14h51.4m	+19°06'	4.7, 7.0	~7"	~310° (1989)
			12.6	66.7"	348° (1953)
			9.6	148.9"	286° (1953)
Beta Scorpii	16h05.4m	-19°48'	2.6, 10.3	0.5"	132° (1959)
			4.9	13.6"	21° (1976)
Nu Draconis	17h32.2m	+55°11'	4.9, 4.9	61.9"	312° (1955)
Epsilon 1 Lyrae	18h44.3m	+39°40'	5.0, 6.1	2.6"	357° (1976)
Epsilon 2 Lyrae			5.2, 5.5	2.3"	94° (1975)
Albireo (Beta Cygni)	19h30.7m	+27°58'	3.1, 5.1	34.4"	54° (1967)

Object: Star name. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Mags.:** V magnitudes of component stars. **Sep.:** Separations of stars in arcseconds. **P.A.:** Position angles in degrees; year of measurement in parentheses.

the bluish secondary is itself a close binary star. Its companion orbits once every 61 years in a highly elliptical path. At widest separation, this 6th-magnitude star is barely visible in an 8-inch telescope. The star will reach greatest elongation (0.55") in 2013. Over the next few years this third component of the Gamma Andromedae system will become visible in large amateur scopes, southeast of the secondary.

As autumn turns to early winter, the region of Orion rises up in the early morning sky before dawn. One of the sky's great delights, the Orion Nebula (M42), again becomes a favorite star party target as observers try to see its misty green light before dawn drowns it out. The central star in M42, **Theta 1 (θ 1) Orionis**, is more easily visible than the nebulosity.

Even a glance with a small telescope shows that Theta 1 Orionis is a multiple star system. Called the Trapezium, Theta 1 contains four bright stars glowing at magnitudes 5.1, 6.7, 6.7, and 7.9. These stars were designated Theta 1 A, B, C, and D, in order of right ascension. All four shine with blue-white light and appear to break through the soft, greenish glow of the nebulosity.

Sharp-eyed observers will spot other faint members of the Trapezium family. In 1826, F. G. W. Struve discovered an 11th-magnitude companion star only 4" to the north of Theta 1 A, and a second 11th-magnitude orb can be glimpsed about 4" southeast of star C. Now known as Theta 1 Orionis E and F, respectively, both can be glimpsed in 6-inch telescopes when seeing is steady.

These are just a few of the thousands of double stars that await amateur telescopes. Why not start compiling your own favorite double star list? Before you know it, you will have built a personal catalog of some of the finest sights found anywhere in the sky. □

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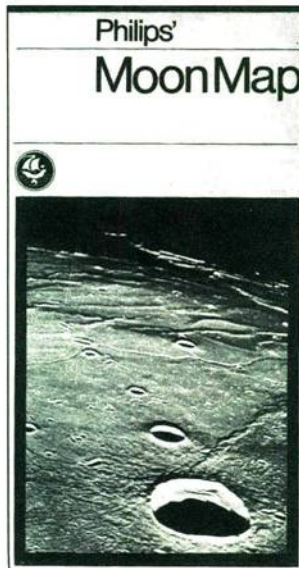
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ASTRONOMY Tests the Northern Lites Cold Camera

An innovative design promises to revive interest in cold-camera technology among astrophotographers.

by Robert Reeves

Unfortunately, cooled-emulsion photography, the practice of chilling film in a camera to make it more sensitive, has the reputation among many astrophotographers of being an esoteric pursuit, one that few attempt and even fewer master. Although cold cameras often produced breathtaking results, they weren't exactly fun to use.

The people at Northern Lites, a small Canadian manufacturing company, believe their new cold camera, designed by veteran astrophotographer Jack Newton, will establish the cold camera as an alternative to conventional methods of prime-focus astrophotography.

With such a gauntlet thrown, ASTRONOMY decided to take the Northern Lites cold camera through its paces. I shot a few rolls of film with the camera to evaluate the final photographic results as well as how the camera handled in the field. My conclusion: It looks like Northern Lites has a winner on its hands.

The Cold Camera Advantage

To understand the advantage of a cold camera for astronomical photography, it's important to know how film behaves during the lengthy time exposures typically used for deep-sky photography. Astronomers noticed long ago that film is faster, that is, it records light faster, when it is exposed on cold nights. They also discovered that the sensitivity of the film increases as the temperature decreases. This fact eventually spawned the development of cooled-emulsion photography, in which film is chilled by dry ice or some other means during its exposure.

Ordinary film loses its effective speed during long exposures because of reciprocity failure. This effect basically slows the film's speed during a long exposure until the effective speed reaches zero. A particular film may start out soaking up photons like a sponge, but the longer you expose,

the slower it gets. Further exposure adds overall density to the film but does little for bringing out the image.

Reciprocity failure can be eliminated two ways: gas hypersensitization (whereby film is "soaked" in a mixture of nitrogen and hydrogen gas) or subjecting the film to very low temperatures during the exposure. Both methods dramatically reduce the amount of exposure time needed to record faint light. Gas hypering, however, fogs film slightly, and the color balance also changes, sometimes in undesirable ways.

Freezing film in a cold camera avoids fogging the film and preserves the color balance, but operating the cold camera has always been a real hassle. My attempts at using older cold-camera designs were so frustrating that I developed a number of psychological barriers that prevented me from continuing cold-camera work. Specifically, these were caused by the awkwardness of handling dry ice, the cumbersome vacuum systems used to prevent frost on the film, fumbling with single-frame film chips used in previous cold-camera designs, and focusing and locating deep-sky objects with a camera you cannot see through.

The Simplified Cold Camera

Jack Newton has designed a cold camera that eliminates these barriers and simplifies the photographic process to the point where novice astrophotographers can now get into cold-camera work just like the veterans.

When the camera arrived, it was packed in a classy black carrying case with the name "Jack Newton Cold Camera" embossed on a brass plaque. I was impressed by the camera body's high-quality construction and fine-tolerance machine work. Because of the need for low-heat transfer within the body of the camera, it is made mostly of heavy black plastic with metal reinforcements. The critical

cold-conducting film pressure plate is polished metal. A generously large film advance knob and finger nuts on the camera body make using the camera a simple task even with winter-numbered hands. After a few minutes of familiarizing myself with the frost-eliminating optical plug and the shutter mechanism, I was ready to shoot.

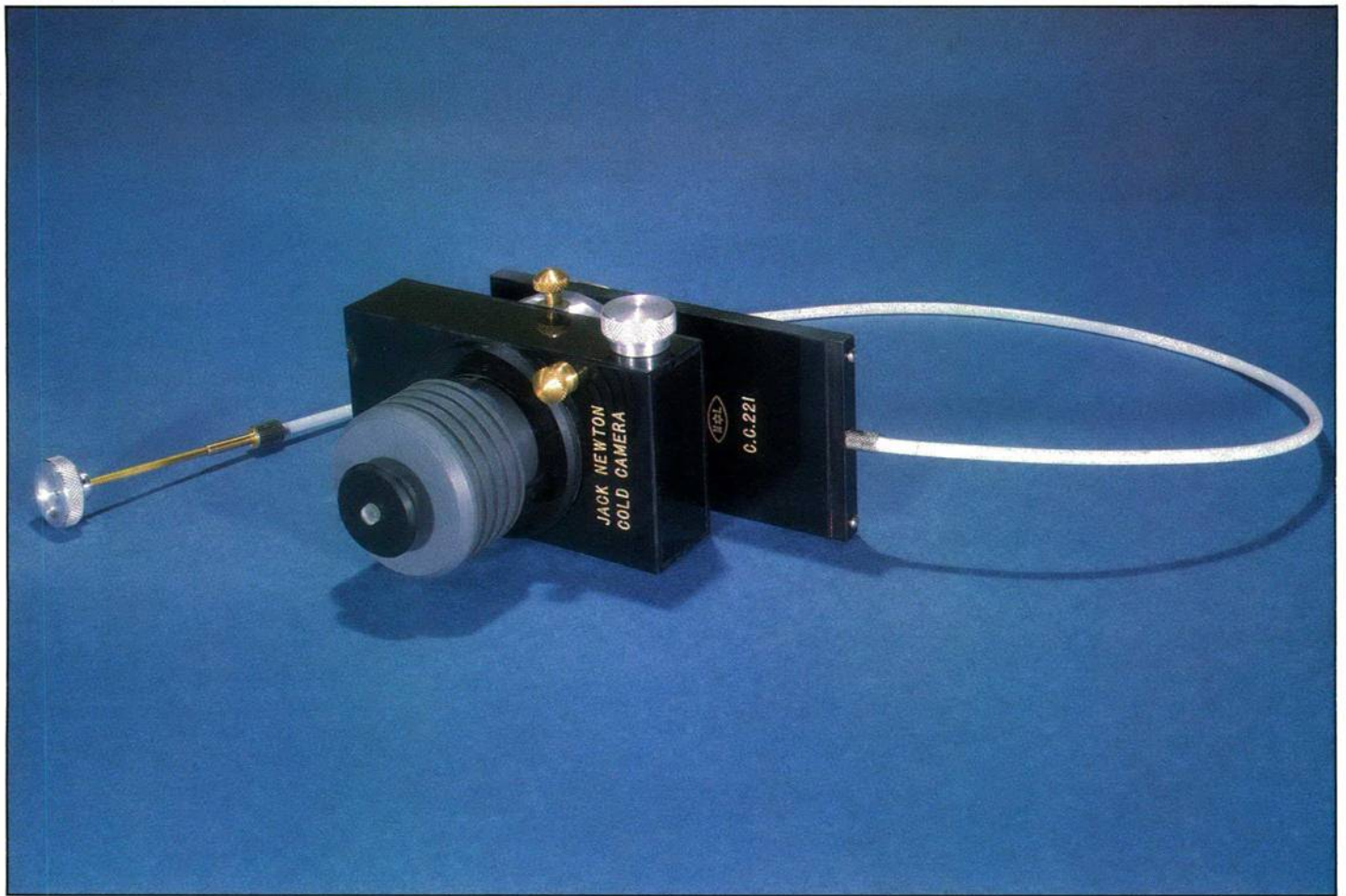
The cold camera is equipped with a 2-inch mounting collar that inserts into either a 2-inch eyepiece focuser or the 2-inch bore on the back of a large off-axis guider. For 1.25-inch mounts, an optional universal mounting ring is available that takes the place of the 2-inch collar. This universal ring has internal T-mount threads that attach to the back of popular-brand off-axis guiders for 8-inch SCTs or other telescopes.

One of the best features of Northern Lite's cold camera is the shutter mechanism — at last, a professional quality, vibrationless slide shutter on a commercial astrocamera. Most camera shutters induce vibrations when they are engaged. Although these vibrations are slight by terrestrial photographic standards, they are enough to jiggle delicate star images.

The cold-camera shutter is operated by drawing the plunger out of a long, heavy-duty cable release. Maintaining slack in the cable release casing while performing this maneuver results in no perceptible movement of the camera. This design is one of the best I have seen for this application. It also eliminates the old problem of thrashing with the telescope-camera combination while trying to pull a slide out of the camera body by hand.

Shoot with Roll Film

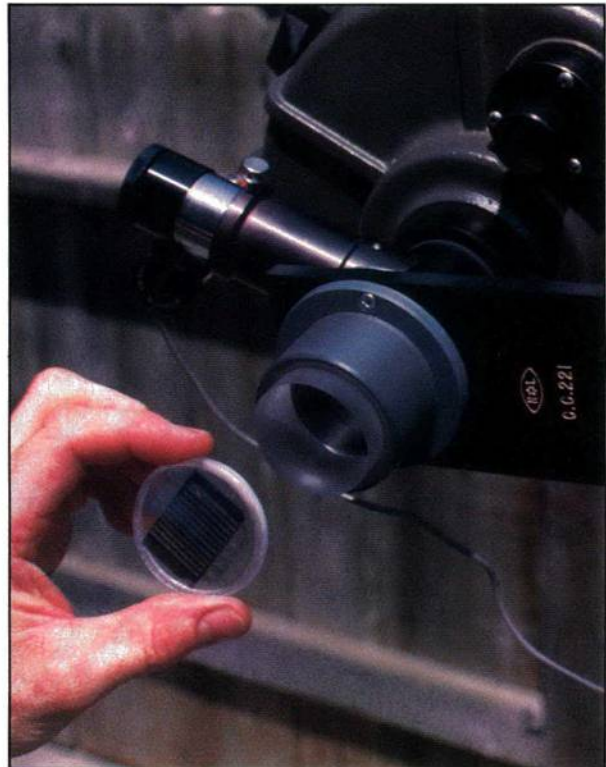
Another advantage is that the cold camera uses roll film just like a conventional 35mm camera. The film unwinds from its original cassette and feeds into a take-up cassette after the exposure. This is an enormous im-



AN ALTERNATIVE TO CONVENTIONAL CAMERAS, the Jack Newton cold camera by Northern Lites may spark a renewed interest among amateur astronomers in cooled-emulsion astrophotography.



THE DRY-ICE CHAMBER screws onto the back of the camera to keep the film cold.



THE FOCUSING TOOL fits over the back of the optical plug and acts like a knife-edge focuser.



DUST LANES surrounding the center of the Andromeda Galaxy are visible in this 10-minute exposure using Konica 3200 film. Photo by Robert Reeves.

provement over previous designs that used single-frame film chips (with their inherent problems of film storage and processing). It is now possible to take a roll of cold-camera exposures in for commercial development, instead of having to develop film chips yourself or use an expensive custom lab.

The Northern Lites cold camera also frees you from having to operate a vacuum pump to draw moisture away from the film during the time it is frozen with dry ice. An optical plug made of clear plastic butts up against the emulsion and presses it against the cold pressure plate, preventing frost from forming on the film while it is cold. This seals the film from the atmosphere during the cold period. The front and rear of the optical plug

are polished flat and have no effect on the image.

The insulating properties of the plastic optical plug keep the film chilled to -100°F and prevent the extreme cold of the dry ice from seeping through the plastic to form dew at the front of the plug, even after a 30-minute exposure. The optical plug, however, must be handled with extreme care. Because the plug is plastic, its flat faces are easily scratched by rough handling. Also, the plug must be dust-free when pressed against the film. Dirt on the plug leaves shadows on the developed film, which appear as black spots.

Focusing Is a Snap

The Northern Lites cold camera is basically a box camera, so how well does it focus when you can't even see through it? The answer: very well indeed. The focusing tool included with the camera pins down the exact focus with absolutely no guesswork. This tool acts like a knife-edge focuser,

but is actually a grating with twelve broad occulting bands. Because there are so many "knife edges," it is easy to sight past one of them to view a bright star during focusing.

The tool is simple to use. After attaching the shutter mechanism and optical plug to the telescope or off-axis guider, you place the focusing tool over the optical plug. The focal plane of the cold camera is at the rear of the optical plug; hence this is where the focus is checked.

While viewing a bright star through the focuser, align the tool so its bands are perpendicular to either right ascension or declination, then gently shift the telescope tube back and forth so the "knife-edge" bands chop the star's image.

At this point, you see an image of the telescope's primary mirror illuminated by the star through the focusing tool and optical plug. If the telescope is out of focus by even the slightest amount, the mirror's image will slowly

The Jack Newton Cold Camera

Manufacturer: Northern Lites, R.R. 1, 801 Stanhill Place, Victoria, British Columbia, V8X 3W9.

List price (U.S. dollars): Cold camera: \$199.95; Universal adaptor ring: \$18.00; Carrying case: \$9.95

Pros: Easy to use, vibrationless shutter, uses roll film, infallible focusing device.

Cons: Fragile optical plug, cannot view field through camera.

THE NEWTON COLD CAMERA breaks down for easy storage in its carrying case (not shown).



disappear from one side to the other, like a curtain being drawn across the star. When the focus is correct, the image will vanish all at once as the scope is moved back and forth. Once the telescope is focused, the rest of the cold camera slides over the optical plug until the plug pushes the film tightly against the cold-conducting pressure plate.

But how do you locate your celestial target when you can't see through the camera? A good finder scope or accurate setting circles will come into play here. Not being able to view the target directly through the camera — a holdover from previous cold-camera designs — is the only problem with Northern Lite's cold camera.

Handling Dry Ice

I used to think that finding and storing dry ice for several days would be a real problem, but this is not so. Aside from the usual commercial dry-ice suppliers, which are usually closed on weekends, many ice cream parlors sell dry ice by the pound. These places are also open late and on weekends, accommodating last-minute decisions to go cold-camera shooting.

To use dry ice in Northern Lite's cold camera, it must be crushed into snow. The easiest way to do this is to place chunks of dry ice between about ten layers of newspaper and pound them with a heavy hammer. Two pounds of crushed dry ice fills a one-quart, glass-lined vacuum thermos bottle. Enough dry ice for an evening's shooting lasts about a week if the thermos bottle is kept in a deep

freeze. The cap on the thermos bottle must be left loose, or the subliming ice will pressurize the thermos and shatter the glass lining.

Handling crushed dry ice in the dark, even barehanded, is no problem with this camera. The dry-ice chamber unscrews from the back and fits perfectly over the mouth of a one-quart thermos bottle. Simply cap the open thermos mouth with the camera's ice chamber, pull back on the chamber's spring-loaded plunger, and invert the chamber-thermos combination. Even when full, the plastic ice chamber insulates your fingers from the cold for several minutes, more than enough time to screw the chamber on to the back of the camera. When the exposure is complete, the remaining dry ice in the camera's chamber can be dumped back into the thermos for later use.

After each exposure, before you advance the film or refocus, the dry-ice-cooled camera pressure plate must be warmed before the cold camera body can be removed from the shutter and optical plug assembly. To do this, a hair dryer comes in handy. It is fascinating to watch the back of the pressure plate, frozen to -100°F , while the hair dryer blows on it. The air from the dryer is hot enough to blister your finger, but for two minutes frost forms in the air stream because the metal pressure plate is so cold!

A word of caution: Once the camera itself is warmed and ready to return to the telescope for the next shot, double check the optical plug to make sure it has also warmed up and

is not coated with dew. Moisture from a dew-covered optical plug will ruin the next exposure when the film is pressed against it and becomes frozen.

One feature I particularly like is the click stop on the film-advance knob. Even in the dark, you can feel when the film has been advanced the necessary two full turns between exposures.

To sum up, the Northern Lites cold camera, with its roll film and optical plug design, is extremely easy to use. Its rugged construction insures that you'll be photographing with it for a long time. The focusing tool supplied with the unit takes all the guesswork out of focusing. The dry ice operation eliminates the need for lengthy film hypersensitization and its accompanying need for quick film processing.

The Northern Lites cold camera is an outstanding value that will make a fine addition to every astrophotographer's equipment arsenal. The astrophoto in this article is from my first attempt at using the cold camera. The camera's simple design and high quality contributed to my achieving six out of seven successful shots on my first try. What happened to the seventh shot? That was my fault: I forgot to close the shutter when I put the camera onto the shutter assembly. □

Robert Reeves is an amateur astronomer and expert astrophotographer living in San Antonio, Texas. His most recent article, "Charting Mountains on the Moon," appeared in the August 1988 issue.

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A FLARE-UP ON THE SUN

On the morning of March 6, 1989, an enormous flare erupted along the eastern limb of the Sun. Such flares are brief releases of energy through the Sun's upper chromosphere that dramatically heat the surrounding gases, sometimes causing an event visible in white light. Dozens of observers witnessed and photographed the giant flare, which turned out to be one of the largest of the decade. The flare sent a blast of radiation that left its effects on Earth.

During the week that followed, solar activity sharply rose as a series of large flares and a host of smaller ones burst forth. This gave solar observers, especially those equipped with $H\alpha$ filters, the chance to see spectacular flare details. Although flares are best visible with $H\alpha$ filters, some events are visible optically.

"It was the first solar flare I had ever seen," said Barbara Wilson of the Houston Astronomical Society. "I was visiting my father in California and brought along a 5-inch scope. We looked at the Sun one afternoon and were astonished to see a huge flare. It looked like a complex 'hot spot' on the Sun's disk, surrounding a dark, magnetic storm."

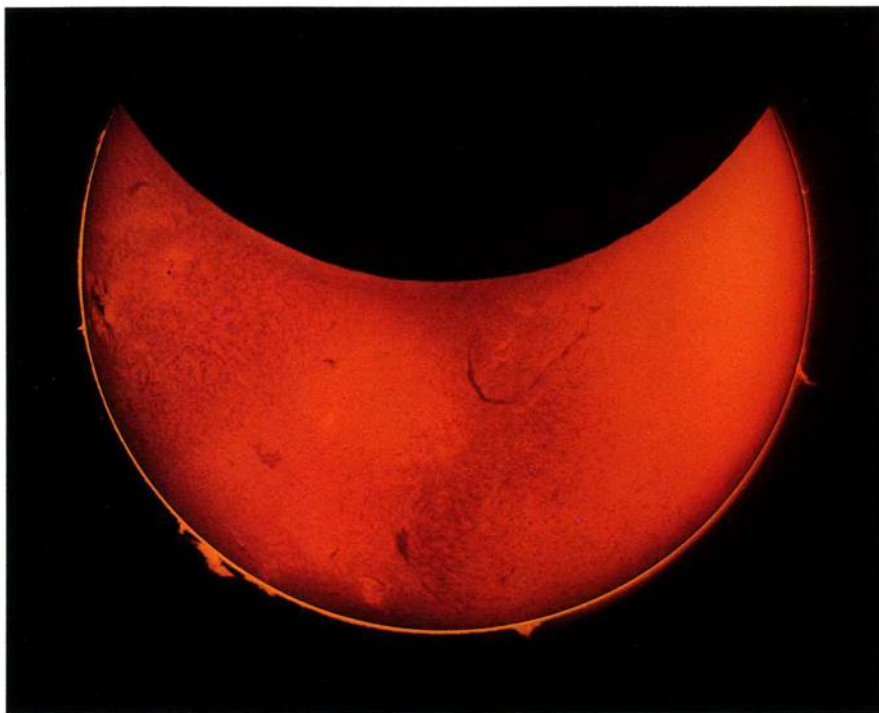
John Hicks of Keswick, Ontario, produced an unusual, dramatic photograph of the flare that erupted on March 11. "I enjoy shooting solar flares and got lucky on the 11th at 3:00 p.m. EST, when I caught a massive flare. I used an 8-inch f/10 SCT with a Daystar 0.8 angstrom solar filter and Tech Pan film."

"Additionally," Hicks continued, "I use a Celestron neutral density filter to slow down the photographic speed to the point that I can use the 'hat trick' to make one-second exposures. This ensures nice images because I don't jiggle the scope by pressing the cable release while exposing. The resulting photo is a composite of a Tech Pan negative registered over a positive transparency of the same event on Ektachrome 200. I rephotographed this with a slide duplicator using a Tungsten bulb, which produced a photo of the flare that resembles a *Solar Max* shot."

On the same morning, Frank J. Melillo watched and photographed the flare from Franklin Square, New York. "At about 10:40 a.m. on the 11th, I spotted a large flare and photographed it with an $H\alpha$ filter fitted on my telescope," said Melillo. "Some thirty-five minutes later I noticed the flare had largely dissipated but displayed small filaments of light for some time."



OUTSIZING EARTH, a huge loop prominence swirls around the limb of the Sun on January 22, 1989. John Hicks of Keswick, Ontario, made this image by combining a Tech Pan negative and a color slide made at the same time into a composite photo.



AN ECLIPSE VIEWED IN HYDROGEN-ALPHA shows the Sun's active outer layers. Reginald Poole photographed the Sun during the partial eclipse of March 7, 1989, through an $H\alpha$ filter with an 0.7 angstrom bandpass and masked the Moon's disk in the darkroom.

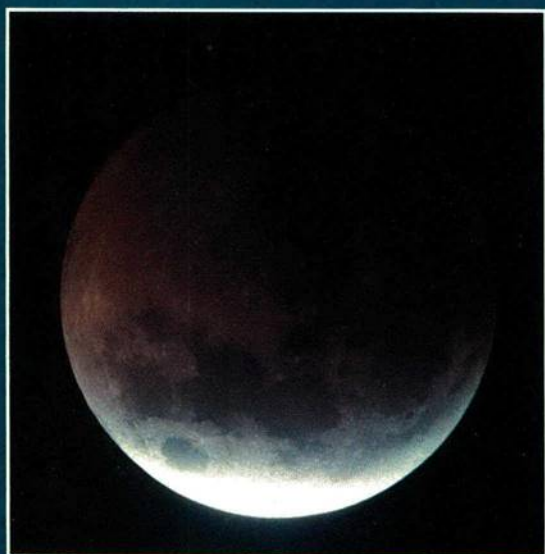
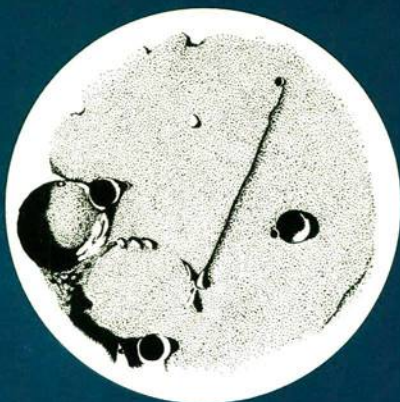
MARCH'S SPECTACULAR AURORA

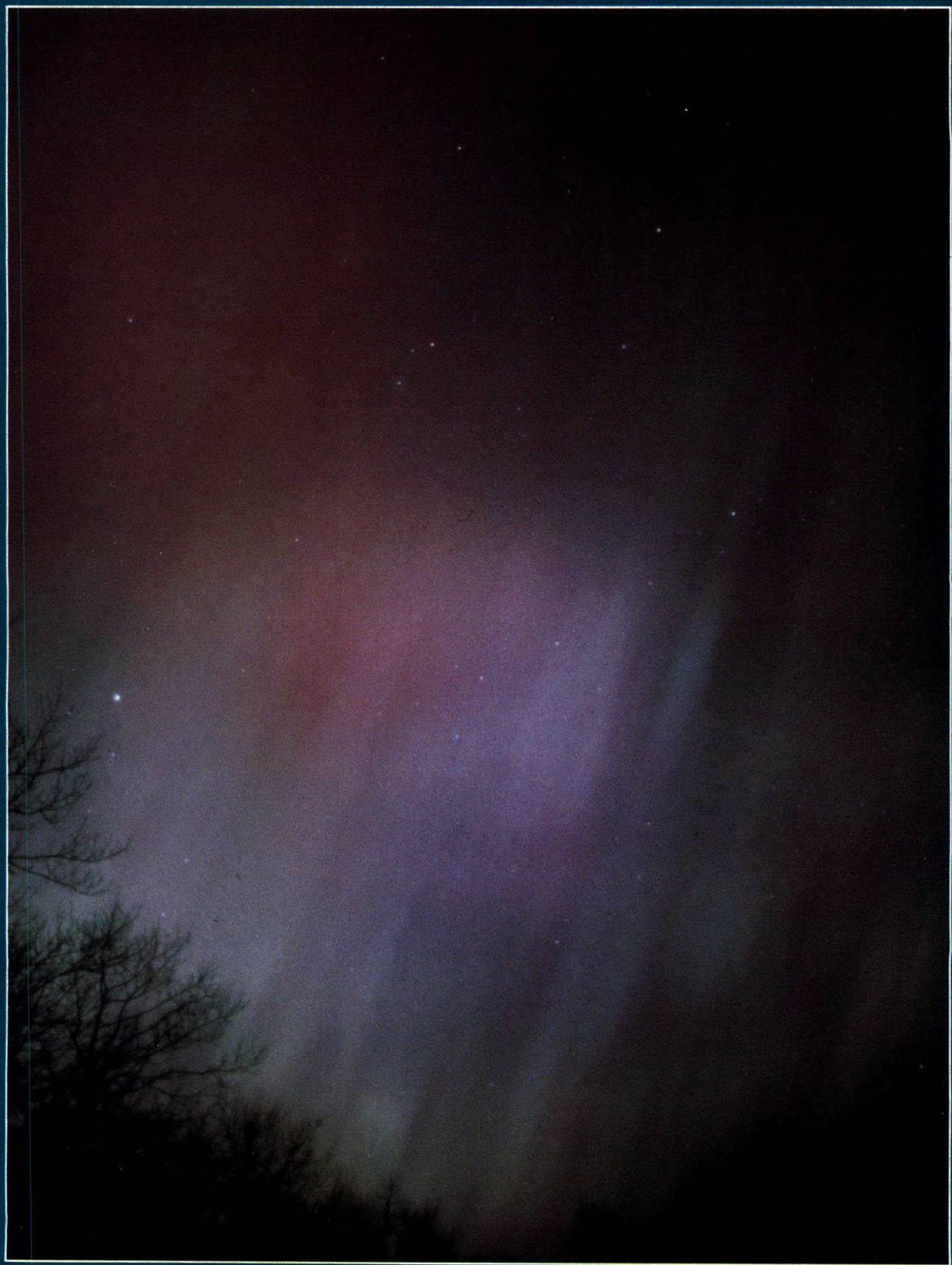
On the evening of March 13/14, 1989, observers across the Northern Hemisphere and as far south as Florida, Arizona, and Southern California, saw a magnificent display of aurorae. The unusual activity followed a series of powerful solar flares several days earlier.

Alan and Susan French's photo of the aurora cascading through Hercules (opposite page) is this month's \$100 "Best Astrophoto" award winner. The Frenches used a 35mm f/2 lens, Ektachrome 400 film, and a 20-second exposure. The camera rested on a tripod during the unguided exposure.

By all accounts, the March aurora appeared unusually red. Michael Sandras captured the ruddy color in a photo made from near New Orleans (below). Outside of Tempe, Arizona, Tom Polakis recorded the aurora's light as it danced over a cactus (left, bottom).

The return of spring got observers outside again and the Moon was a favorite target. Elaine Clark photographed the lunar eclipse of February 21, 1989, as it appeared from Queensland, Australia (left, center). She used an 8-inch f/5.6 reflector, 200 ISO film, and a 2-second exposure. Astronomical artist Howard Moore III of Hartsville, South Carolina, sketched the lunar Straight Wall last March 15 with an 8-inch f/10 SCT at 450x (left).





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BRILLIANT AURORAE PRODUCED BY SOLAR FLARE

Last March's solar flares produced some of the best auroral displays in over a decade, stretching as far south as Florida, Arizona, and Southern California. A particularly brilliant and active display occurred on the night of March 13/14, caused by solar radiation interacting with molecules in Earth's atmosphere. Because auroral displays generally follow about twenty-six hours after a flare, the March 13/14 display was caused by one of the smaller flares, not the big one on March 7. Nevertheless, the March 13/14 aurora was for many the best they had ever witnessed.

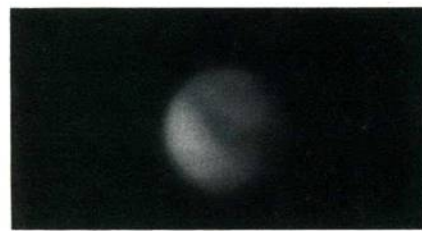
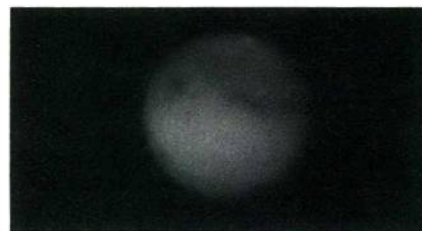
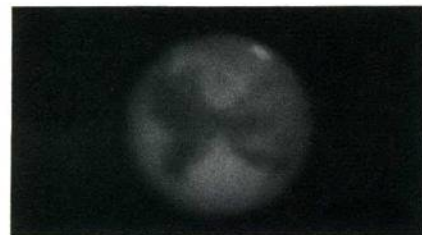
Tim Printy of Orlando, Florida, recounted how on the evening of March 13 he saw an aurora for the first time. "That night will be remembered by members of the Central Florida Astronomical Society for many years to come," said Printy. "At 8 p.m. EST I walked outside my home and noticed what appeared to be a large number of jet contrails overhead. A glance at the Moon, then approaching First Quarter, revealed an area of very

reddish sky surrounding it. I thought there might be a fire nearby, but I hadn't heard any sirens. Then it hit me — an aurora visible from Florida!

"I immediately began calling our club's members and informing them," Printy recalled. "The club president, Doug Monington, kept calling people as I grabbed every available camera and began shooting away. The sky overhead was a delicate red. Bands of light danced across the sky and to the north I saw glowing sheets of blue and green light. By 9:30 p.m. the activity subsided and an hour later the show was over. But Floridians had witnessed a great aurora. Many of those who saw an aurora for the first time were baffled, thinking that the sky activity might be related to the space shuttle that was launched that morning."

"The dominant feature of the March 13 aurora was a series of red rays, some longer than 40°," Monington said. "They flickered slowly and turned the sky into a soft pink color, especially near the Moon. The greatest activity occurred between Ursa Major and Leo."

West of the Orlando observers and along the same line of latitude (approx-



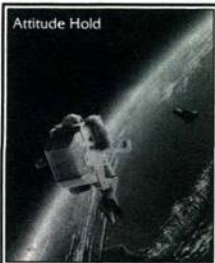
MARTIAN SURFACE DETAILS such as Syrtis Major (top) and Solis Lacus (center) were visible as Mars receded last autumn. Daniel Koehler of Waukesha, Wisconsin, used a 12.5-inch f/9 reflector, Tech Pan film, a #25A filter, and 1-second exposures.

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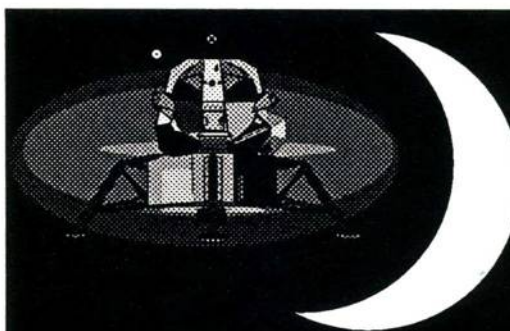
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mately 30° N), Michael D. Sandras of the Pontchartrain Astronomical Society viewed the March 13 show from the town of Westwego near New Orleans. "The aurora began as a rose-colored hue emanating from the northeast," said Sandras. "Within forty-five minutes I detected bands of light extending south into Orion. It was an unusually warm, summer-like evening, and the aurora caused quite a stir. Local television stations interrupted broadcasts to spread the word on the unexpected sky show."

Northern observers had their share of excitement over the aurorae, too. Alex Scholten of Eerbeek in the Netherlands said that on March 13 he saw "several colored 'clouds' with spectacular rays and weak curtains attached to them. The aurora wasn't confined to the northern horizon but extended all over the sky. Such a spectacular display of northern lights hasn't been observed in the Netherlands since 1938."

Michael Boschat of Halifax, Nova Scotia — an observer accustomed to frequent aurorae — observed a "most excellent" display on March 13. Boschat said, "The display consisted of long coronal



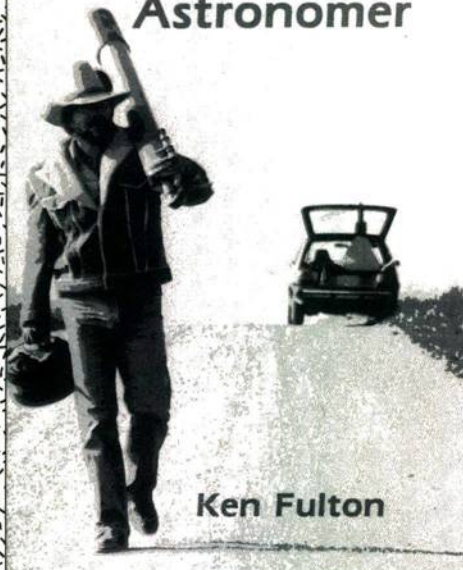
A GIANT SUNSPOT GROUP was rotating toward the Sun's limb on March 11, 1989. Bill Harris and Doug Finch photographed the event from Birmingham, Alabama, using a Genesis refractor and Tech Pan film.

rays of green and red extending from the zenith to the horizon. The rays appeared to move and were startling because some were bright red, almost like laser beams. Red rays and glows appeared in the west, south, and east, and other parts of the sky

retained a greenish cast. The March 13 event was a spectacular, rare display of northern lights. It was like standing underneath a giant, glowing umbrella of multicolored, undulating lights." — David J. Eicher □

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THE HOMING INSTINCT

As dawn rolls onto the Atlantic coast like the tide, two pigeons, nested in the deepest corner of a cave, stir and flex their wings. This particular cave is unlike any that these pigeons have nested in before. Instead of rough rock and dirt, the walls are made of smooth metal plates. This cave is not set in a cliff but is a giant, horn-shaped box sitting on stilts. Strangest of all, the whole box occasionally rotates completely around. Yet pigeon instinct insists that this is a good dwelling place, so the pigeons are happy here. It is home.

The pigeons waddle to the mouth of the cave and sun themselves. After an hour, two cars drive up and two humans get out. These humans come here all the time and they are always loading and unloading stuff. The pigeons turn and waddle back into the cave.

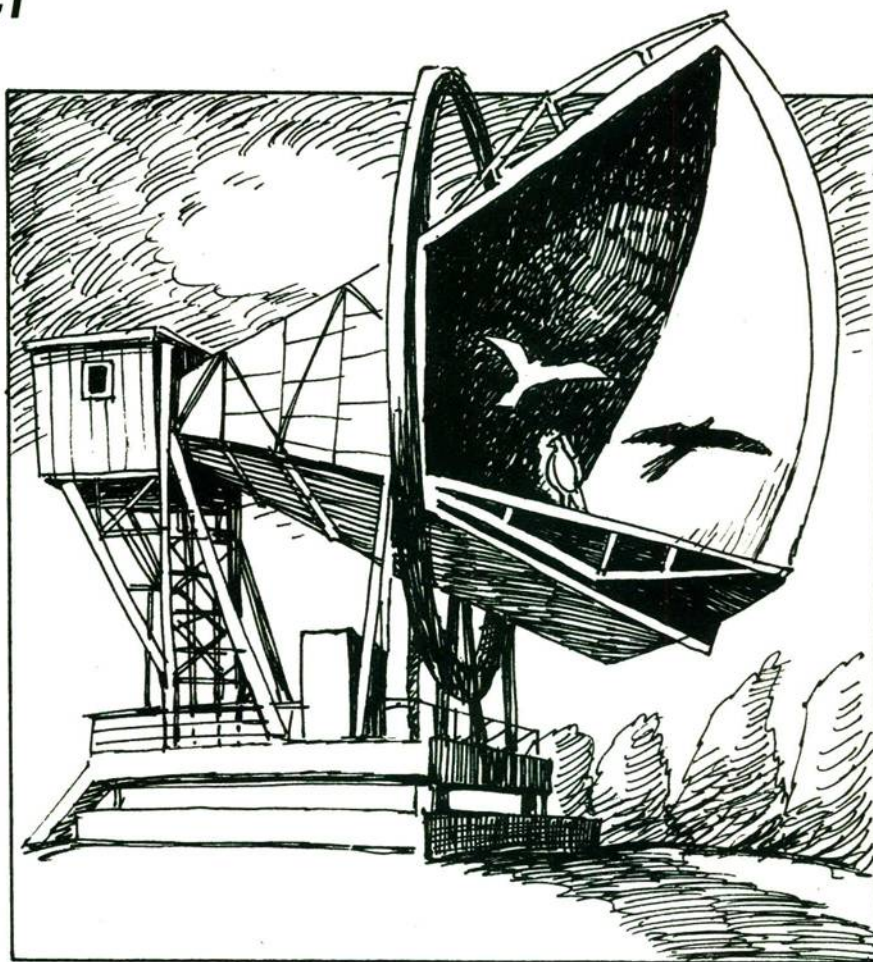
Before the pigeons realize what is happening, nets swoosh down and tangle them wing and foot. The humans carry the pigeons outside and place them in a cardboard box.

After awhile the pigeons feel themselves being lifted and carried and set down. There are noises and vibrations for a long time. When they cease, the lid of the box is opened, and the pigeons fly out. Looking about for the safety of their home, they see nothing familiar. They don't know where they are.

Yet the pigeons had no reason to worry. They only needed to tune in to the energies flowing through space to find their way home. With the biological compass inside their heads, they focus on Earth's magnetic field and feel its intensity and direction. Having figured out the general direction of home, the pigeons rise into the sky.

Back at the pigeons' cave, which is a microwave antenna in Holmdel, New Jersey, the two humans, Robert Wilson and Arno Penzias, measure the intensity of the static in the antenna. Though it seemed unlikely that the pigeons had been putting out much heat, which the instruments detected as static, the scientists had tried everything else they could think of to account for the static. Once the pigeons were gone, the static decreased a little, but most of it remained. It still read about 3 kelvins.

The static couldn't be coming from a manmade source either, like a satellite or radio tower. No matter which direction of the sky the antenna was pointed, day or night, the static remained the same. It was almost as if the heat was spread evenly



through the sky.

Through his window an astrophysicist could see the evening light fading into darkness over the Princeton campus. Yet he doesn't take much notice, for he is gazing through another kind of window at a much vaster sky, at a much more dramatic transition between darkness and light. This window is simply a pad of paper in his lap.

Every so often he studies the equations on the pad of paper before adding more. As the numbers lead him onward, he sees more and more clearly the first moments after the Big Bang. He sees space ballooning outward. He sees the churning of powerful forces. He sees a menagerie of elementary particles. He sees the particles swarming about and fusing. And he sees energy of fantastic intensity.

The theory that the universe began like this was still new and unproven in the 1940s and 1950s. But the astrophysicist had an idea. By knowing which particles had formed in the Big Bang and knowing how much energy was needed to form them, he could calculate the intensity of

the energy of the Big Bang. Because the universe had been expanding ever since, this radiation should have steadily cooled as it spread. If he could calculate how intense this radiation should be today, perhaps scientists could build instruments to measure it and he could prove that the universe really did begin in a Big Bang and was expanding.

After several hours of work he has an answer. The radiation that was trillions of degrees in the Big Bang should be only a few kelvins today. That was awfully cold. The astrophysicist gazes into the night, feeling sure this energy just had to be out there.

Suddenly he hears a strange fluttering sound at the window. He leans forward and sees that it is just two pigeons settling on his window ledge.

As the Sun rises, the pigeons fly on. Though flying over unfamiliar land, they plot their course with keen precision. They are drawing not just on their own experience but on the experience of all their pigeon ancestors.

The pigeons begin to see familiar land-

scape. At last they spot their home and swoop down to it. They land on the lip of the antenna and waddle inside. Their search is over.

The pigeons had no idea that their home is actually a giant version of the sensing device inside their heads. It too detects the energies flowing through space but with far more sensitivity than any living organ could. It is the newest of hundreds of giant instruments that humans use to survey the universe. And though no one knew it yet, this particular antenna could measure the energy that remained from the Big Bang.

The horn-shaped antenna was the culmination of the 4 billion-year-long process of life discovering its place in the world. Humans had arisen, and in their hands life progressed to making homing instruments out of metal, glass, and electronics. These instruments had to be even larger because humans wanted to discover their place in a much larger realm — the universe.

Yet humans were searching for more than just their physical location in the universe. The human mind ached for a deeper kind of belonging. Humans wanted to know where they had come from and how they fit into the world. They longed to feel at home.

Humans have studied their physical place in the universe to discover their metaphysical place in the universe. When they realized that the 3-kelvin static in the antenna was the remnant of the Big Bang, humans would discover their ultimate location, that they and all the universe were flying out of a Big Bang.

We were taking the measure of the stars so that we could take a measure of ourselves. We have drawn heavy inferences from what we took to be our physical location, such as being in the center of the universe or being one speck among millions spread across a vast darkness. We discovered that we arose through the workings of immense and complicated forces — the forces of the cosmos and the forces of evolution on Earth.

Perhaps not even this would be enough to satisfy the human need to know where they belonged in the universe. Perhaps in humans the need to belong had become unanswerable, for the location, origin, and meaning of the universe were unanswerable. Yet for the life that began finding its location by dimly sensing differences of warmth in an ancient sea, to have discovered its place amid all the warmth and cold, all the light and darkness, all the emptiness of the universe — that was to have discovered a great deal.

— Don Lago

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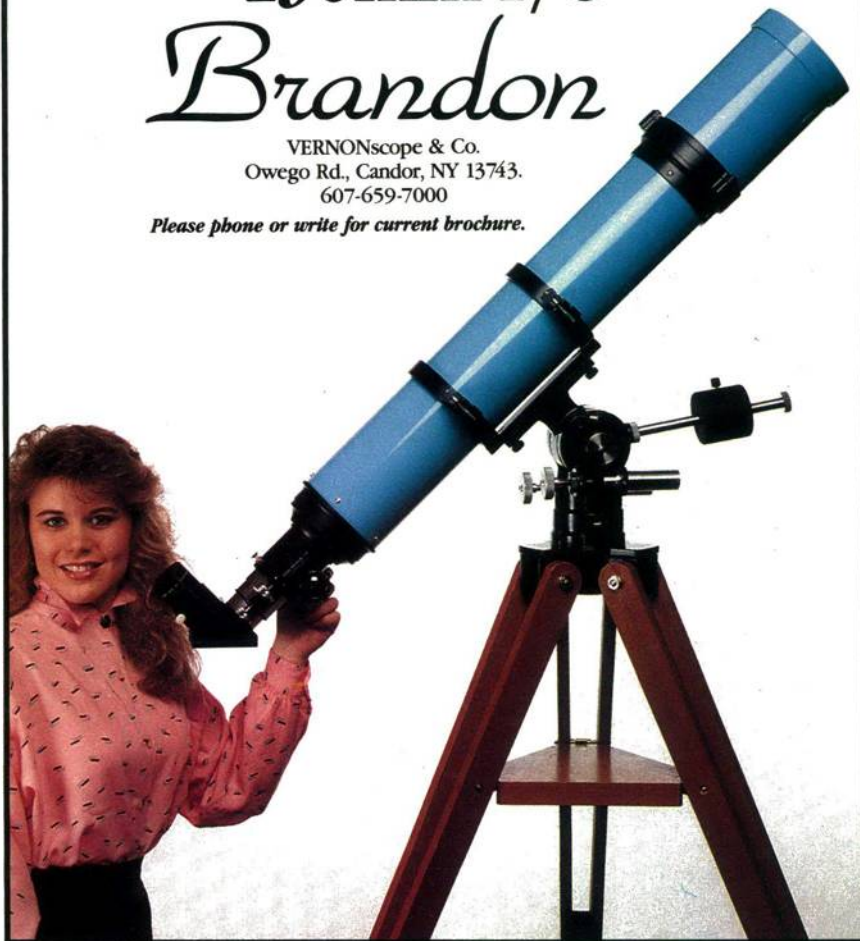
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AN ASTRONOMICAL DYNASTY

Resolute and Undertaking Characters: The Lives of Wilhelm and Otto Struve by Alan H. Batten, (D. Reidel, 1988), ISBN 90-277-2652-3, hardcover, 259 pages, \$62.

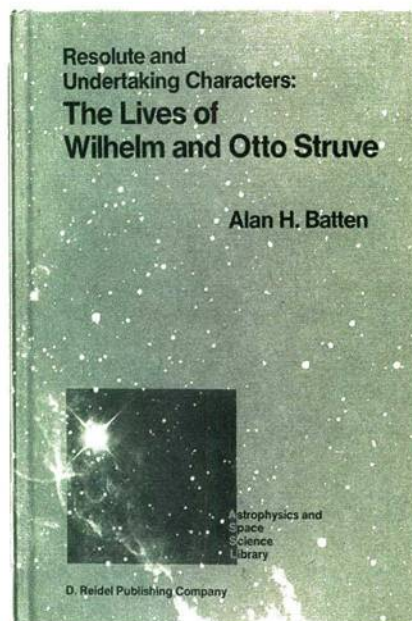
The history of astronomy contains some remarkable "family dynasties" of astronomers. One such astronomical dynasty, the Struves of Germany, began in the nineteenth century and continues to the present day. Alan Batten, a Canadian double star astronomer, has written a fine biography of the first two Struves in the family line.

Beginning with Friedrich Georg Wilhelm Struve (1793-1864), the Struve family contributed seven individuals to astronomy over five generations. Of the seven, three attained world renown. By focusing on the first two astronomers in the family — Wilhelm (as he was generally known) and his son, Otto (1819-1905) — Batten has done a skillful job of weaving the history of nineteenth-century astronomy into the personal stories of these two famous astronomers.

The lifelong astronomical interests of both Wilhelm and Otto centered on double and multiple stars. Throughout most of the nineteenth century, such star systems were at or near the leading edge of research. Careful micrometrical measurements of separations and position angles of stellar components allowed astronomers to calculate orbits for many double and multiple stars, thus deriving their masses. This laid an essential physical foundation on which astrophysics could build.

Batten starts his tale with Wilhelm's ancestry. Born in northern Germany, Wilhelm Struve was one of fourteen children. He was sent to school in Hamburg, but contemporary politics intervened in his education one day in the form of a French press gang, who seized the well-grown lad for the military. For a time he was locked in a second-floor room but escaped by jumping from the window and fleeing into Holstein, a neighboring Danish principality not under Napoleon's control. From there he was sent by his family to Dorpat (now Tartu) in Estonia, where an older brother was living.

After graduating from university in Dorpat, Wilhelm remained there and soon landed a position teaching mathematics and astronomy. The job also included the directorship of the university's observatory, and Wilhelm happily spent the next quarter-century there, improving the equipment until it included



what at the time was the world's largest refractor, a 9-inch made by Joseph Fraunhofer.

During this time, Wilhelm married, raised a family, and published two major works on double and multiple stars. He left Dorpat in 1839 to take over as director of the new Pulkovo Observatory, erected by Tsar Nicholas I near St. Petersburg (now Leningrad) in Russia. By that time, Wilhelm's 20-year-old son Otto was beginning his own career as an astronomer.

Otto quickly grew to throw a professional shadow fully as large as his father's. In 1845 he was appointed vice-director of Pulkovo under Wilhelm, and upon Wilhelm's retirement in 1862, Otto took over as director. He continued Wilhelm's double star observations and expanded them in his own catalogs of measurements. Otto resigned the directorship in 1889 but lived until 1905, seeing two of his sons establish astronomical careers as well.

Anyone interested in astronomical history will certainly enjoy this book (despite its hefty price tag). But its potential readership is larger still: If you're an observer, you may have noticed the stars with Σ (Wilhelm Struve) and $O\Sigma$ (Otto Struve) designations in Norton's *Star Atlas*, Burnham's *Celestial Handbook*, and other observing guides. These stars include some of the prettiest pairs you'll ever see.

By giving you a glimpse of the two men who compiled much of the original

data on double and multiple stars, Alan Batten's book lets you vicariously step back into the old observatory dome and join these two great observers of a century and more ago. — Robert Burnham

RICHARD FEYNMAN: EXPLORER AND PHYSICIST

What Do You Care What Other People Think? by Richard P. Feynman, W. W. Norton and Company, 1988), ISBN 0-393-02659-0, hardcover, 256 pages, \$17.95.

If you believe that most scientists are obsessed with weighing all that they see on a scale counterbalanced by inviolable physical laws and equations, you should read this book. It's difficult to believe that the writer was one of the century's greatest physicists and a Nobel Prize winner to boot. The late Richard Feynman demonstrates in this book, as he did in *Surely You're Joking, Mr. Feynman* published a few years ago, that he was hardly the stereotypical physicist.

Feynman's book is a collection of vignettes and reminiscences, both humorous and touching, from his life as a young boy, a student, and a working scientist. He credits his father with instilling in him his interest in science and especially with giving him his unique way of thinking about the world.

The most poignant chapter is the one from which the title comes, "What Do You Care What Other People Think?" This was a statement his first wife, Arlene, taunted Feynman with whenever he became overly concerned about what other people might think about his actions. Arlene, who was diagnosed with Hodgkin's disease, died shortly after their marriage. Feynman used to commute between the Albuquerque hospital where she lay dying and Los Alamos where he was working on the atomic bomb. It was Arlene's unabashed attitude toward life, says Feynman, that infused him with the inclination to ask "dumb questions" in science without feeling embarrassed.

The latter half of the book, "Mr. Feynman Goes To Washington," covers Feynman's experiences as a member of the Rogers Commission investigating the Challenger accident. His methods, at times exasperating to the more bureaucratically entrenched members, aptly illustrates his rare ability to look at problems from different perspectives. At last we find out the story behind Feynman's O-ring and ice-water demonstration conducted during one of the public meetings. This simple experiment revealed the primary cause of the accident.

Feynman's style of storytelling is unusual and not at all like the lofty sentiments you'd expect from an eminent scientist. He relays events simply, without academic overtones or excess verbiage. Many times he challenges the "rules" of storytelling and infuses a series of flashbacks within an ongoing event or follows a tangent instead of adhering to the story line. But the reader can't help but forgive. Feynman's style is so engaging, his observations both humorous and unexpected, that it is difficult not to turn the page to see what adventures he encounters next.

Feynman's book presents the convictions of an explorer who insistently avoids the well-trodden paths, both in life and in science. It is the final testament of a scientist who extolled imagination as much as critical thinking in the search for truth. — Jeff Kanipe

THE GALAXIES AS THEY ARE

The Color Atlas of Galaxies by James D. Wray, (Cambridge University Press, 1988), ISBN 0-521-32236-7, hardcover, 189 pages, \$79.50.

It took twelve years but now it's done, and it was all worth it. James Wray, an astronomer at the University of Texas, has produced a remarkable collection of color photographs of over six hundred galaxies. Although it's intended for the professional astronomer, why should they have all the fun? This is a book many amateurs will want to have on their shelf, both as a reference work and observing guide.

As Allan Sandage points out in the foreword, Wray's atlas is remarkable for two reasons. First, all of the colors of these galaxies are true, in other words, a correct color balance was painstakingly maintained at all brightness levels. The blues of young, hot stars in spiral arms and the yellows and oranges of old stars in ellipticals are quite apparent.

Second, Wray maintains the correct relation of surface brightness from galaxy to galaxy. You can compare the surface brightness of M101 with that of NGC 1042 and see the obvious differences in the distribution of various stellar populations in these two similarly shaped systems.

Fully half of the book's content consists of color plates illustrating the diverse form, color, and detail of all galaxy types. There are a number of full-page photos, including a mosaic of the spiral NGC 253 in Sculptor and an intriguing image of the sprawling irregular galaxy NGC 4449 in Canes Venatici. Typically, each page con-

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tains four to eight plates. The facing pages consist of the data pertinent to each photograph and to the galaxies themselves.

Those readers who value astronomy aesthetics will no doubt be delighted, but deep-sky observers interested in the nature of galaxies will most likely get the most out of this book. The brief descriptions of each galaxy on the facing page enumerate some of the intrinsic properties that shape each galaxy. The tabular information includes exposure data, the observatory and telescope used, the blue magnitude, the blue-minus-the-visual magnitude (subtract the B-V from the B to obtain the visual magnitude), the galaxy type as determined by both the de Vaucouleurs and the Hubble and Sandage classification systems, and orientation data (where north lies in the photo).

This is a work not only of fundamental importance for science but also of exceptional beauty. — Jeff Kanipe

NO RUN-OF-THE-MILL TEXTBOOK

Contemporary Astronomy, fourth edition, by Jay M. Pasachoff, (Saunders College Publishing, 1989), ISBN 0-03-023247-3, softcover, 643 pages, \$22.

Not all astronomy textbooks are historical rehashes, H-R diagrams, black body curves, and over-published photos of celestial objects. Some textbooks can be downright fun to look through, not to mention effective teaching tools. One of these is the fourth edition of *Contemporary Astronomy*.

Jay Pasachoff, director of the Hopkins Observatory at Williams College in Massachusetts, is known for his use of diverse and sometimes unusual graphic elements in his efforts to vitalize the staid college textbook format. For example, in a chapter on light and telescopes, we see a photograph of actors Steve Martin and Daryl Hannah standing next to a Newtonian telescope. The scene is from the movie *Roxanne*, in which Hannah plays a graduate student in astrophysics. Above the photo is a detailed diagram of a reflector. Although this is not the presentation you'd expect in a typical textbook, it does lighten the mood a bit.

In this edition, Pasachoff includes passages of new photos, many not often seen by the general public. At astronomical meetings and symposiums, Pasachoff attends news conferences and requests images and scientific papers from astronomers. He works hard, and his efforts benefit readers by providing them with the latest in astronomical imagery and research. The new images in this edition

include photos of the nucleus of Comet Halley from the *Giotto* probe; photos of Mars, the Galilean satellites, and the Uranian system from NASA, JPL, and the U.S. Geological Survey; plus stunning color plates of nebulae, star clusters, and galaxies.

The opening of each chapter contains an "Aims" statement, which sets the course for the coming content. The conclusion of each chapter offers a concise summary, key words, and questions. Much of the text has been revised and rewritten, and there are new chapters on Uranus, comets, supernovae, pulsars, and black holes. The textbook is over one hundred pages longer than the previous edition.

The publishers have also made a number of ancillary materials available, including a teacher's guide and overhead-projection transparencies of selected artwork and photographs from the book.

Contemporary Astronomy would be an excellent choice for college instructors who desire to make their course a more dynamic experience for their students. It would also make a handy reference for teachers and amateur astronomers who want to keep up on the latest in astronomical research. — Jeff Kanipe

ASTROPHYSICS

Neutrinos, edited by H. V. Klapdor, (Springer Verlag, 1988), ISBN 3-540-50166-5, hardcover, 339 pages, \$49.50. A presentation of the current understanding of the nature and properties of the elusive neutrino in particle physics and its impact in astrophysics and cosmology. This is, needless to say, a technical work that should be of interest to particle physicists and serious armchair cosmologists.

Relativity in Astrometry, Celestial Mechanics, and Geodesy by Michael H. Soffel, (Springer-Verlag, 1989), ISBN 0-387-18906-8, hardcover, 298 pages, \$59. A specialist's book on applying relativity to practical problems such as clock synchronization, laser ranging to satellites or lunar reflectors, and very long baseline interferometry. Soffel also reviews how relativity influences measuring techniques and data in the fields of astrometry, celestial mechanics, and geodesy.

COSMOLOGY

The Extragalactic Distance Scale, edited by Sidney van den Bergh and Christopher J. Pritchet, (Astronomical Society of the Pacific, 1988), ISBN 0-937707-21-X, hardcover, 385 pages, \$32. Proceedings from a symposium held in June and July

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1988 at the University of Victoria, in British Columbia, Canada. This is one of the most thorough and up-to-date assemblies of research papers from the field of the extragalactic distance scale. Many of the key researchers — including Paul Hodge, Sidney van den Bergh, and Allan Sandage — submitted papers, making this a collective statement about the techniques and viability of determining distances in the universe. Topics include overviews of distance indicators, Cepheid distances to nearby galaxies, planetary nebulae as distance indicators, the distance to the Virgo Cluster, and deviations in the motions of nearby galaxies. The papers are technical (sometimes to an extreme), but considering the authors are mainly talking to each other, the topics, with some amount of concentration, are comprehensible to the layman.

General Relativity: A Guide to Its Consequences for Gravity and Cosmology by J. L. Martin, (John Wiley and Sons, 1988), ISBN 0-470-21183-0, hardcover, 176 pages, \$39.96. At first glance, Martin's book might scare away those not comfortable with the "Schwarzschild metric" and the "Riemann tensor," but the writing is in a breezy, friendly style, and there is a lot to be gained from reading between the equations. Of course those with mathematics and physics backgrounds will gain much more from this thorough treatment.

SOLAR SYSTEM

Mercury, edited by Faith Vilas, Clark R. Chapman, Mildred Shapley Matthews, (University of Arizona, 1988), ISBN 0-8165-1085-7, hardcover, 794 pages, \$45. Considering the number of pages and the quantity of information contained in this book on the iron-rich, Sun-blasted planet, *Mercury* is a great buy for educators, planetary scientists, and solar-system enthusiasts. The result of an outgrowth of a professional conference held in Tucson in August 1986, *Mercury* contains the latest research from forty-seven authors across many disciplines. Topics covered include Mercury's origin, metal-rich composition, cratering history, and atmosphere.

The Planet Neptune by Patrick Moore, (John Wiley and Sons, 1988), ISBN 0-470-21366-3, hardcover, 144 pages, \$29.95. Considering the upcoming *Voyager* flyby, this may not be the best time to bring out a book on Neptune. At least half of the book consists of a summary of our knowledge of the planet and will no doubt have to be rewritten. The other half

covers the search and discovery of the planet, plus other historical information. The historical accounts at least are complete, and make good preparatory reading for the *Voyager* flyby. The cover features a photograph of the beautiful telescope used by Galle and D'Arrest to identify Neptune in 1846.

Meteorites and the Early Solar System, edited by John F. Kerridge and Mildred Shapley Matthews, (University of Arizona, 1988), ISBN 0-8165-1063-6, hardcover, 1,269 pages, \$55. This huge book covers the entire field of meteorite research, particularly what meteorites have revealed about the evolution of the solar system: Chapters include overview and classification of meteorites, age of the solar system, research on parent bodies of meteorites, and nucleosynthesis. This is a reference work for researchers, but it will also attract serious amateur astronomers interested in meteorites.

THE SUN

The Physics of Solar Flares by Einar Tandberg-Hanssen and A. Gordon Emslie, (Cambridge University Press, 1988), ISBN 0-521-30804-6, hardcover, 273 pages, \$69.50. Another state-of-the-art knowledge book, this time on solar flares. The book has two main parts. The first part addresses the essentials of solar flare physics, such as the shapes of flares, elements of flare magnetohydrodynamics, and nuclear processes. The second part is a thorough look at the various aspects of flare phenomena, from energy release mechanisms to coronal ejections. This text is primarily aimed at the graduate student already versed in basic physics.

SPACE

The NASA Mars Conference, edited by Duke B. Reiber, (published for the American Astronautical Society by Univelt, Incorporated, 1988), ISBN 0-87703-294-7, softcover, 534 pages, \$30. The proceedings of the NASA Mars conference held in July 1986 in Washington, D.C., covers three broad areas: our current understanding of Mars, planned and future unmanned exploration, and options for a manned exploration. Although there is much technical information, the essentials are not beyond the layman's understanding. A sample of the paper topics include Martian volcanism, geology, meteorites from Mars, and living on Mars. A fine fold-out color display section contains photographs and geological maps of the planet as well as artists' conceptions of proposed missions. □

SETI ON VIDEO

The Quest for Contact, (Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112), 32 minutes, VHS only, \$35.95.

The search for extraterrestrial intelligence (SETI) enjoyed a boom in public attention throughout the mid-1970s. Since then, however, the field has been less visible, although work continues among the relatively few professional astronomers actively following the subject.

Compared to the somewhat overheated public statements made by SETI proponents a decade ago, the researchers interviewed on the video (Frank Drake, Carl Sagan, Bernard Oliver, Paul Horowitz, and Phillip Morrison, among others) sound practical, down-to-earth, and almost deliberately nonflamboyant. This struck me as a good idea. Besides being a sensible approach to a project with little likelihood of an early payoff, it also forestalls the kind of public enthusiasm that turns cynical when anticipated results do not emerge "on time."

So, rather than grandstanding about "Them," the video begins with a look at the well-known Drake Equation and soberly lays out the scope of the problem facing any SETI researcher. And it isn't an easy one — SETI requires that we search the entire sky over an appallingly large number of individual radio frequencies with a highly sophisticated level of sensitivity. Only recently have radio astronomers built receivers of what they hope is adequate sensitivity and simultaneous bandwidth and devised computer software that can scan tirelessly through mountains of data for a non-natural signal.

To help the viewer visualize past SETI projects and provide a handle on what is being done now, the video employs a clever three-dimensional graphical device, a cube in "parameter space." This is less abstruse than it sounds. Think of a cube of graph paper whose three axes are radio frequency, detector sensitivity, and percentage of the sky examined.

If you plot a limited search of a few stars at a single wavelength to a low sensitivity (Drake's OZMA search of 1960) in the cube, it doesn't occupy much space. On the other hand, the all-sky search NASA is undertaking now will fill much of the cube. Whether or not the search will be successful is an open question, but the parameter-space cube shows that for the first time a really thorough search

is being done.

Given that SETI is a research project with no conclusion in sight, the story inevitably is left hanging. But there is little sense of let down at the end of the video because the viewer knows all along that there's no news yet. My only complaint concerns technical stuff: In a couple of places the music track is loud enough to override the voice of the narrator or the scientist who is explaining what he does.

Given the perennial popularity of the topic with college-age students, I think this is a video that any astronomy department would want to have. It comes with a bibliography of books (including science fiction novels) and articles for anyone wanting to take their interest further. How well it will appeal to a general astronomy audience, however, is less certain, especially given its relatively short length and moderately high price.

— Robert Burnham

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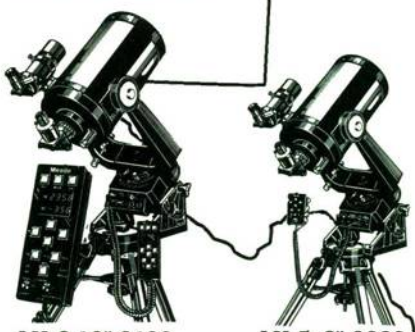
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FOR SALE — Dynamax 8 SCT, new wedge, latitude adjuster, tripod, three eyepieces, 8x50 finder, 2" diagonal, and other accessories. Good condition. \$650. Contact Rex Thompson, 40 Raymond, San Anselmo, CA 94960. Phone (415) 453-3342.

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Meetings and Events

June 21-25

Centennial Meeting of the Astronomical Society of the Pacific, University of California at Berkeley. Contact: Berkeley Meeting Information, A.S.P., 390 Ashton Avenue, San Francisco, CA 94112.

June 23-24

4th Annual Sedona-Verde Valley Astrophotography Festival: Milky Way Galaxy, Verde Valley Preserve of Thousand Trails, Arizona. Contact: Russell A. Nidey, Verde Valley Astro-Center, 1101 Zalesky Road, Cottonwood, AZ 86326.

June 24

Annual Summer Solstice Celebration and Star Party, East Detroit, Michigan. Sponsored by the Warren Astronomical Society. Contact: Alan Rothernberg. Phone: (313) 344-2854.

June 27-30

1989 Biennial Meeting of the Planetarium Association of Canada, Montreal, Quebec. Hosted by Dow Planetarium. Contact: Nicole Patenaude. Phone: (514) 872-4530.

June 30-July 2

Astronomical League Mid-States Regional Convention, Tulsa, Oklahoma. Sponsored by the Astronomy Club of Tulsa. Contact: Newel Pottorf. Phone: (918) 742-7577.

June 30-July 2

Starstare Star Party, Colorado Springs, Colorado. Sponsored by the Colorado Springs Astronomical Society. Contact: CSAS, P.O. Box 62022, Colorado Springs, CO 80917.

July 1

Star Bash, Huntsburg, Ohio. Sponsored by the Chagrin Valley Astronomical Society. Contact: Don Himes, P.O. Box 11, Chagrin Falls, OH 44022. Phone: (216) 247-5114.

July 1-31

Moon-Moonta, West Palm Beach, Florida. 20th anniversary celebration of *Apollo 11* sponsored by the South Florida Science Museum and the Astronomical Society of the Palm Beaches, Inc. Contact: Gary Bogner, 4801 Dreher Trail North, West Palm Beach, FL 33405. Phone: (407) 832-1958.

July 8

Annual Convention of the Cuyahoga Astronomical Association, Hiram, Ohio. Contact: Allen Jenks, P.O. Box 29089, Parma, OH 44129. Phone: (216) 237-4223.

July 16-24

Spaceweek, Baton Rouge, Louisiana. Sponsored by the Baton Rouge Astronomical Society, Inc. Contact: Mark Stauffer, 17324 Gains Mill Avenue, Baton Rouge, LA 70817.

July 16-24

Spaceweek, Lafayette, Louisiana. Sponsored by the Lafayette Natural History Museum and Planetarium. Contact: Donna Savoie. Phone: (318) 268-5544.

July 19-22

Astronomical League National Convention, Spokane, Washington. Hosted by the Spokane Astronomical Society. Contact: Gene Dietzen, P.O. Box 8114, Spokane, WA 99203-0114. Phone: (509) 928-2313.

July 20

Return to the Moon Party, Market Square Park, Baltimore, Maryland. Sponsored by the Baltimore chapter of the National Space Society. Phone: (301) 879-3602.

July 28-29

2nd Annual Ozarks Star Party, near Branson, Missouri. Sponsored by the Ozarks Telescope Makers and Amateur Astronomers. Contact: Greg Blount, P.O. Box 165, Cape Fair, MO 65624. Phone: (417) 538-4553.

July 28-29

14th Annual Public Star Night, Saskatoon, Saskatchewan. Sponsored by the Royal Astronomical Society of Canada-Saskatoon Centre. Contact: Jim Young, Box 317, Sub P.O. #6, Saskatoon, Saskatchewan, Canada S7N 0W0.

August 1

Annual Star Party and Picnic, Winchester Canyon Gun Club, Santa Barbara, California. Contact: Clyde Kirkpatrick, P.O. Box 3702, Santa Barbara, CA 93130. Phone: (805) 685-2705.

August 4-6

Mountain Astronomers Rendezvous and Star Party, Royal Gorge, Canon City, Colorado. Sponsored by the MARS region of the Astronomical League. Contact: Dave Trott, P.O. Box 10814, Denver, CO 80210. Phone: (303) 871-5172.

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Readings and Resources

"At the Foot of the Ladder" (page 22)

First on the Moon by Neil Armstrong, Michael Collins, and Edwin Aldrin, Jr., with Gene Farmer and Dora Jane Hamblin, (Little Brown, 1970). The story of Apollo 11 told in transcripts from the flight and interviews with the crew.

Carrying the Fire by Michael Collins, (Farrar, Straus, and Giroux, 1974). The best of the astronaut memoirs; excellent and highly entertaining.

Return to Earth by Edwin Aldrin, Jr., (Random House, 1973). A firsthand account of what it's like to walk on the Moon and life after Apollo.

Apollo Changed the Moon (page 40)

The Geologic History of the Moon by Don E. Wilhelms, (U.S. Geological Survey Professional Paper #1348, 1987). A lengthy and profusely illustrated survey of lunar knowledge.

The Moon Book by Bevan French, (Penguin, 1977). A very readable, though somewhat dated, guide that weaves an informal history of the Apollo missions into the story of the Moon.

Footprints to Foothold (page 48)

Lunar Bases and Space Activities of the 21st Century, edited by Wendell Mendell, (Lunar and Planetary Institute, 1985). Eighty-seven articles explore every aspect of building lunar bases including the political and economic considerations.

Future Astronomical Observatories on the Moon, edited by Jack O. Burns and Wendell Mendell, (NASA Conference Publication #2489, 1988).

Apollo Landing Sites (page 66)

The Apollo Landing Sites, compiled by James R. Zimbelman, (Lunar and Planetary Institute, Planetary Image Center, 3303 NASA Road 1, Houston, Texas 77058-4399). An excellent slide set that includes many of the photos used in the article. The set is available for \$15.00 plus shipping.

Apollo Expeditions to the Moon, edited by Edgar M. Cortright, (NASA Publications, SP-350, 1975). Available from the U.S. Government Printing Office, this detailed history of the Apollo program includes descriptions of the landing sites and extravehicular activities.

Moon, Mars, and Venus by Antonin Rukl (Hamlyn Publishing Group, Ltd., 1976). Detailed lunar atlas that is unfortunately out of print.

Double Stars (page 78)

Celestial Objects for Common Telescopes by Thomas W. Webb, (Dover, 1962). Reprint of a 1917 book containing many colorful descriptions of double stars.

Observing Visual Double Stars by Paul Couteau, (Massachusetts Institute of Technology Press, 1981). A semitechnical account of double star observing containing an excellent observing list.

Cold Camera (page 86)

A Manual of Advanced Astrophotography by Brad Wallis and Robert Provin, (Cambridge University Press, 1988). Contains a chapter on cold-camera astrophotography by Jack Newton.

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We had three FIRST PRIZE \$500 SHOPPING SPREE winners: Kevin Hodkiewicz of Lena, Wisconsin; Shelly Wilfong of Goshen, Indiana; and Michael Jackson of Charlottesville, Virginia. With his winnings Kevin bought a Meade 784 Quartz drive from Edelman's; from Astro-Tech, a set of Techtron collimating tools and a 16 x 70 RA/Polar finderscope; and from Kalmbach Publishing Co. he purchased *Sky Atlas 2000.0* and *Build Your Own Telescope*. From Northern Sky Telescope Shelly selected a Meade 323 Refractor telescope and purchased *The Universe From Your Backyard* from Kalmbach Publishing Co. Michael selected a Bausch & Lomb 4000 telescope from Focus Camera; and from Kalmbach Publishing Co. he purchased *Introduction to Observing and Photographing the Solar System*, a Moon map and *The Best Deep Sky Objects*.

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WANTED — Early and current data for Alpha and Proxima Centauri including radial velocities, proper motions, right ascension, declination, position angles, parallaxes, and distances. Contact Hugh Turner, Sr., 8772 DeVille Circle, Huntington Beach, CA 92647. Phone (714) 847-3902.

WANTED — Correspondence with individuals interested in astronomy and photography. Contact Jennifer Arnott, P.O. Box 1132, Edgewood, MD 21040.

WANTED — A Mars globe or information relating to the purchase of a Mars globe. Contact Tom Kramer, 233 Candee Avenue, Sayville, NY 11782. Phone (516) 567-7062.

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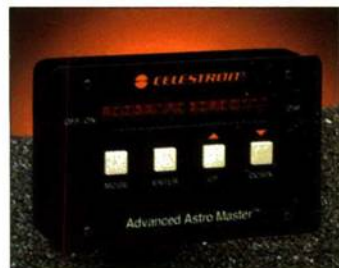
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